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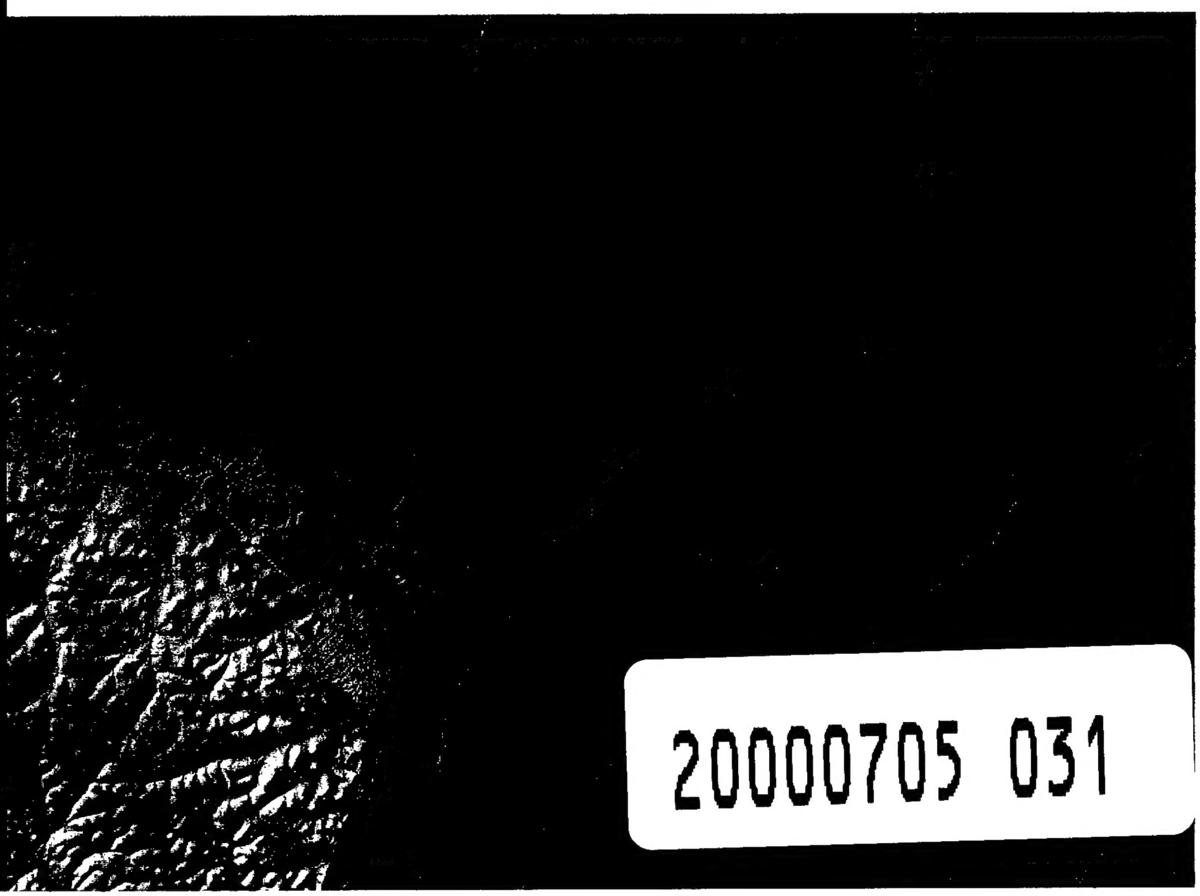
Central California Valley Interferometric Synthetic Aperture Radar (IFSAR) Collection

March 2000

James J. Damron and Carlton Daniel



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13. ABSTRACT *(Maximum 200 words)*

During the winter floods of 1996/97, a proposal was developed by the California Department of Conservation (CalDoc) to use the STAR-3i airborne X-band radar terrain mapping system, operated by Intermap, to acquire Interferometric Synthetic Aperture Radar (IFSAR) Digital Elevation Model (DEM) data. The proposal was funded by the Federal Emergency Management Agency (FEMA), with the U.S. Army Engineer Research and Development Center's (ERDC) Topographic Engineering Center (TEC) as the project manager. The CalDoc proposal included a flight plan to conduct an IFSAR data collection of the Sacramento and San Joaquin Valleys. The goal would be to develop a DEM of the major river channels and their levees, along with the adjacent flood-prone areas. This could be used for advanced planning and improved response in real time. The intent was that by using an IFSAR DEM along with Geographic Information Systems (GIS), one would be able to model the extent of flooding into adjacent areas if a levee were to be breached. Coverage of the flood data set extends from north of Sacramento, south to Fresno, following the Sacramento and San Joaquin Rivers. The project area covers approximately 8,596 square miles or 22,264 square kilometers.

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PREFACE

This research was sponsored by the Federal Emergency Management Agency and managed by the U.S. Army Engineer Research and Development Center's (ERDC) Topographic Engineering Center (TEC) under contract DACA76-92-C-0023, CLIN 0012.

The study was conducted during the period September 1997 to June 1999. Mr. Thomas E. Jorgensen was Chief, Terrain Data Representation Branch, and Mr. William Z. Clark was Acting Director, Topographic Research Division during this period.

Colonel James A. Walter was the Director of ERDC's TEC at the time of publication of this report.

ACKNOWLEDGMENTS

Appreciation is hereby given to the following ERDC/TEC employees who assisted in the review of the applied methodologies used within this study: James Eichholz, Geospatial Engineering Branch, and Jim Shine, Terrain Data Generation Branch. The authors also extend their thanks to the following individuals: Dave Kehrlein, Governor's Office of Emergency Services, State of California, for collecting GPS ground control data, and Robert Yoha, California Department of Conservation, for providing invaluable assistance and guidance on the end-user requirements.

CENTRAL CALIFORNIA VALLEY INTERFEROMETRIC SYNTHETIC APERTURE RADAR (IFSAR) COLLECTION

INTRODUCTION

The California Department of Conservation (CalDoC) developed a proposal to use the STAR-3i airborne X-band radar terrain mapping system, operated by Intermap, to acquire Interferometric Synthetic Aperture Radar (IFSAR) Digital Elevation Model (DEM) data. The Federal Emergency Management Agency (FEMA) funded the proposal, the U.S. Army Engineer Research and Development Center's (ERDC) Topographic Engineering Center (TEC) acted as project manager, and CalDoC provided user input. The planned project area is shown in Figure 1.

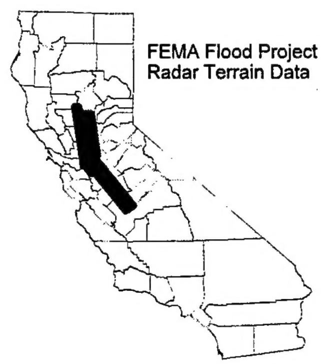

Figure 1. Location Map of IFSAR Collection

Coverage of the data set extends north of Sacramento, south to Fresno, following the Sacramento and San Joaquin Rivers. The project area covers approximately 22,000 km^2 (or 8,500 mi^2). Data were initially collected during September 1997 in two flights, one each for the northern and southern areas. Initially, strong turbulence caused the southern mission to be aborted; it was reflown in July 1998. Intermap began processing data in early 1998 with completion planned for November 1998.

CONTRACTUAL REQUIREMENTS

The STAR-3i data will be processed to produce DEMs and magnitude images. The data sets will be produced in tiles in digital format. The data will conform to the WGS84 horizontal reference system and the Universal Transverse Mercator (UTM) projection. The DEMs will be produced as elevation values on a regular 10-m grid interval in northings and eastings. Each posting represents the mean elevation for that grid interval. Intermap will use its best efforts to reference the DEM to ground level. It should be noted that in areas of heavy vegetation, the radar signal does not penetrate the level beneath the trees. The accuracy of the corrected DEM will be 1.5 m root mean square (RMS). The magnitude image will have a pixel spacing of 2.5 m.

Four generations of DEM products were delivered. CalDoC received the first product delivery in November 1997. CalDoC and TEC received the second product deliveries in March 1998. The third product deliveries were received by CalDoC and TEC from late August through November 1998. Because many of the DEMs required additional editing and processing to meet the RMS 1.5-m specification, the final delivery schedule was first changed to mid-December 1998, then to late January 1999. The fourth product delivery corrected a production problem with the geoid correction file.

Magnitude Image 8 vs. 16 bits

The magnitude data that were collected by the STAR-3i system in late 1997, and post-processed by Intermap and delivered to TEC and CalDoC in March 1998, contained only 8 bits of data. The production of an 8-bit magnitude map did not appear to be consistent with the performance of the sensor when operated by the Environmental Research Institute of Michigan (ERIM). Data analysis conducted at TEC on previous IFSAR data sets that were produced by the STAR-3i sensor, and post-processed by ERIM, indicated a dynamic range of 10 to 12 bits of data. At first, the delivery of an 8-bit magnitude map did not appear to constitute a best effort. Further discussions and evaluations of the sampling methodology used by Intermap were conducted to determine if only 8 bits of data would be required.

To resolve the 8-bit issue, TEC evaluated archived ERIM radar images to see if their dynamic range histograms were significantly different from the Intermap Sacramento Valley images. The ERIM images reviewed were of Fort Hood, TX, Bosnia, Camp Roberts, CA, and Germany. Except for the Camp Roberts data, all of the radar images were similar to the Intermap images. Typical pixel values of natural features such as terrain and vegetation were in the 10-50 range. As with the Intermap data, more than 99.9 percent of the data were less than 255 and pixels that exceeded 255 corresponded to features such as metal building roofs. The Camp Roberts' data fell in a much greater range of pixel values (around 9,000-35,000). It appears that ERIM stretched the data using a mathematical formula. In processing some of the Bosnian radar image data using this formula (10000*log10 (image value)), a similar range of pixel values was achieved. This confirmed that the Camp Roberts' data had been stretched by ERIM and would have fit in an 8-bit data range as did the other ERIM and Intermap images.

FIRST PRODUCT DELIVERY

In November 1997, CalDoC received the first DEM product delivery. The products were delivered in 25 by 25-km tiles. The initial assessment by CalDoC revealed major quality assurance discrepancies. CalDoC's findings revealed the magnitude image to be poorly co-registered with the DEM and the geometry to be greatly distorted. The DEM geometry was distorted to a lesser degree than the magnitude image. Distances and shapes for the DEM did not correlate when plotted to a U.S. Geological Survey (USGS) quad sheet. There were disjointed seams within the mosaic titles that took on the appearance of gaps with no data. The DEM also

did not end at the edge of the collection area, which resulted in a false elevation surface continuing beyond the collection area.

SECOND PRODUCT DELIVERY

In Figure 2, a shaded relief is used to show the extent of the second Intermap DEM data set with an approximate area of 5,550 mi^2 or 14,375 km^2. This delivery is referred to as the Sacramento Valley or north section. The total usable portion of the Intermap DEM has an approximate area of 3,813 mi^2 or 9,876 km^2 shown in Figure 3. The rest of the data outside the boundary area displayed in Figure 3 are ghost data with different values, and were produced during the production of the DEM by Intermap. The Intermap magnitude data set had the same usable area as the DEM data set in Figure 3. The tiling scheme used was a 25 by 25-km tile consisting of 23 files for each DEM and magnitude data set excluding the header files.

Data Formats

The second Intermap DEM data set had an IEEE floating point format, 32-bit signed binary with 10-m post spacing with .bil extensions. A single DEM header file has the Intermap header parameters for file 4225_600.txt in Figure 4. The Geoid: NIMA-96 statement below references the vertical datum used by Intermap. A full file listing of the delivered DEMs is shown in Figure 6 minus their extensions and header files.

File: 4225_600
UTM Zone 10 - WGS-84
Geoid: NIMA-96
upper left easting: 600000.0
upper left northing: 4225000.0
number of rows: 2500
number of columns: 2500
pixel size 10.0m

Figure 4. Second Delivery DEM Header File

The second Intermap magnitude data set had an 8-bit BIL format with 2.5-m resolution and a .img extension. A single magnitude header file is shown with the Intermap header parameters for file 4225_600.txt in Figure 5. The actual delivery of magnitude images was 8 bit and not 16 bit as the header file implies. The data were converted from 32-bit floating points to 16-bit unsigned integer by simply truncating the floating points. A full file listing is shown in Figure 6 minus their file extensions. All header files had the same file name and .txt extensions; precautions were taken to separate the two data sets.

Figure 2. Shaded Relief of Second Delivery Intermap DEM

Figure 3. Usable Area of Second Delivery Intermap DEM

File 4225_600.img

UTM Zone 10 WGS84
upper left easting 599999.5
upper left northing 4225001.0
number of rows 10000
number of pixels 10000
pixel size 2.5m

Figure 5. Second Delivery Magnitude Image Header File

4225_600	4275_625	4350_600
4375_600	4275_650	4350_625
4225_625	4300_575	4375_575
4225_650	4300_600	
4250_575	4300_625	
4250_600	4300_650	
4250_625	4325_575	
4250_650	4325_600	
4275_575	4325_625	
4275_600	4350_575	

Figure 6. File Listing for Second Product Delivery

DEM Anomalies

There were three major anomalies and one major production error associated with the second Intermap DEM delivery. The areas used to illustrate the various anomalies of the second delivery for this report are shown in Figure 7. The first anomaly can be characterized as a north to south linear pattern with a rise and fall pattern moving from west to east across the entire DEM data set. The second anomaly can be characterized as a west to east short linear pattern with a rise and fall pattern moving north to south known as a motion artifact. The third anomaly was associated with water areas. The major production error was caused by an over sampling of the DEM to

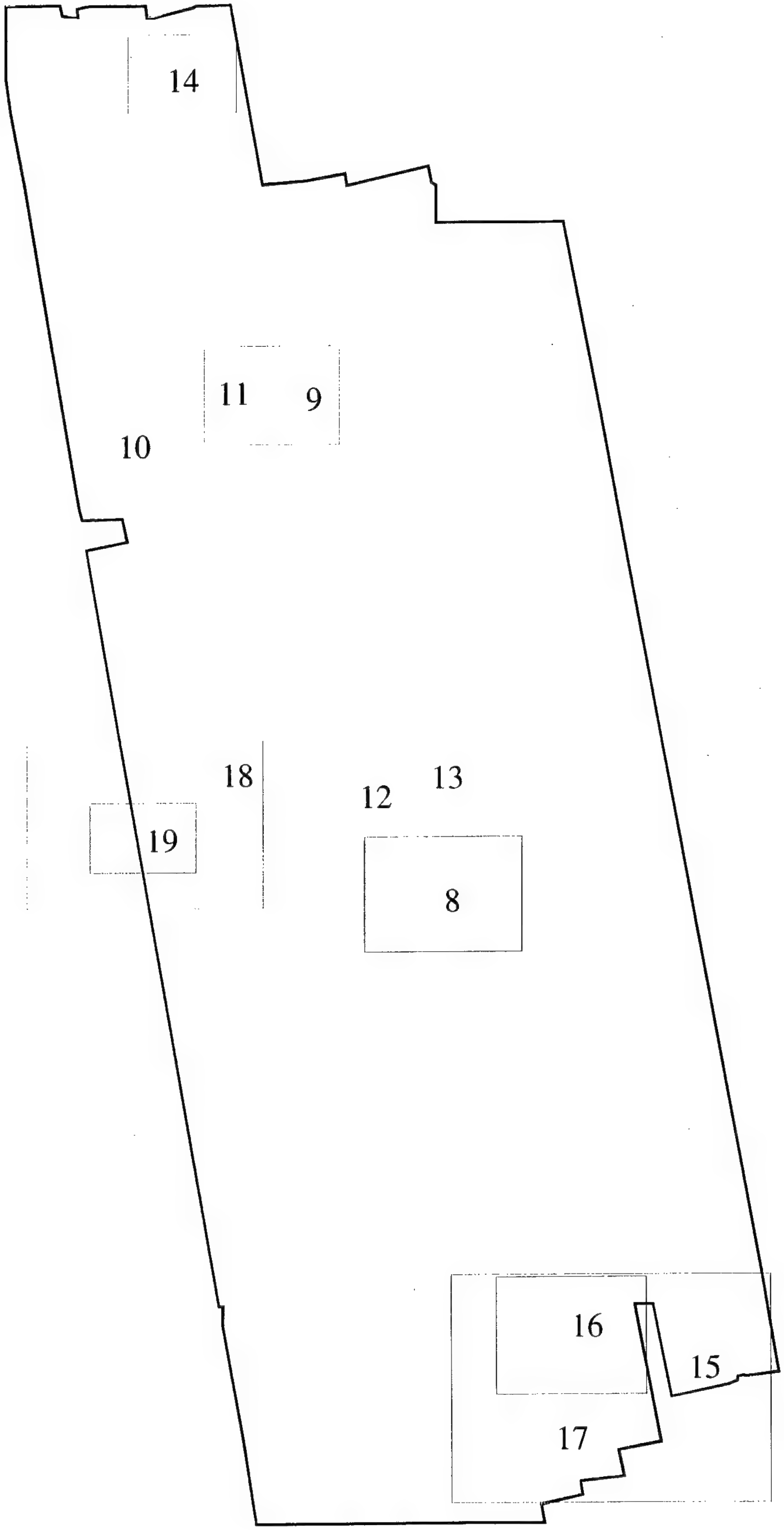

Figure 7. Location of Shaded Reliefs by Figure Number

20 m and down sampling the DEM to 10 m for the second delivery. Figure 7 indexes the images that were evaluated for the second delivery. Figures 8 through 19 display anomalies and artifacts that were introduced by production errors along with sensor-induced errors.

In Figures 8 through 11, the north to south linear patterns and water anomalies are displayed. The north to south linear patterns extend throughout the second DEM delivery with different levels of severity. The water anomalies were associated with areas near levee structures and rivers. The north to south linear patterns and motion artifacts are displayed in Figures 12 through 14. Motion artifacts were associated with flight lines and appear randomly in some of the flight lines. In Figures 15 through 19, the ghost data outside the main DEM are displayed at different locations with north to south linear patterns. The magnitude data set was void of any anomalies that were visible in the quality control checks.

Hydrologic tools in Arc/Info software were used to find out if the anomalies were affecting surface flow. The north to south linear patterns were acting as streams channeling surface flow between the high and low sections of the anomalies. Water anomalies would not allow surface water to flow correctly in the stream and river channels. Motion artifacts displayed the same effects as the north to south linear patterns. All data sets were imported, exported, and compressed to test the operational use of the data and passed without any problems.

Recommendations

Intermap agreed to correct the major production error with the third product delivery. Intermap also agreed to an improved calibration technique used in the southern collection (San Joaquin Valley) to eliminate the anomalies of the second delivery. TEC recommended adding a README file to each CD-ROM with the third product delivery to clarify questions about each data set. TEC and Intermap agreed to a November 1998 delivery schedule for the north and south sections.

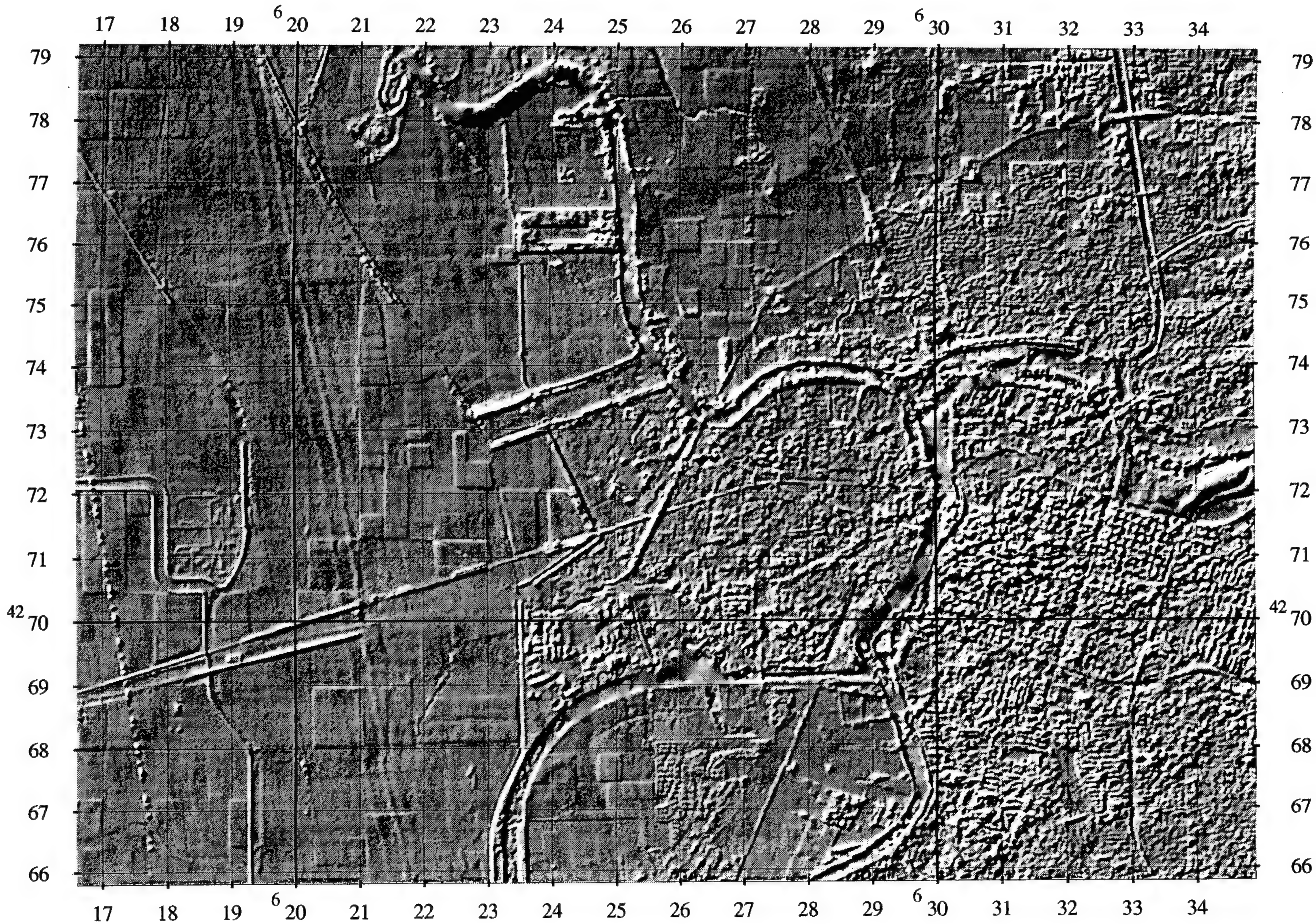

Figure 8. North to South and Water Anomalies

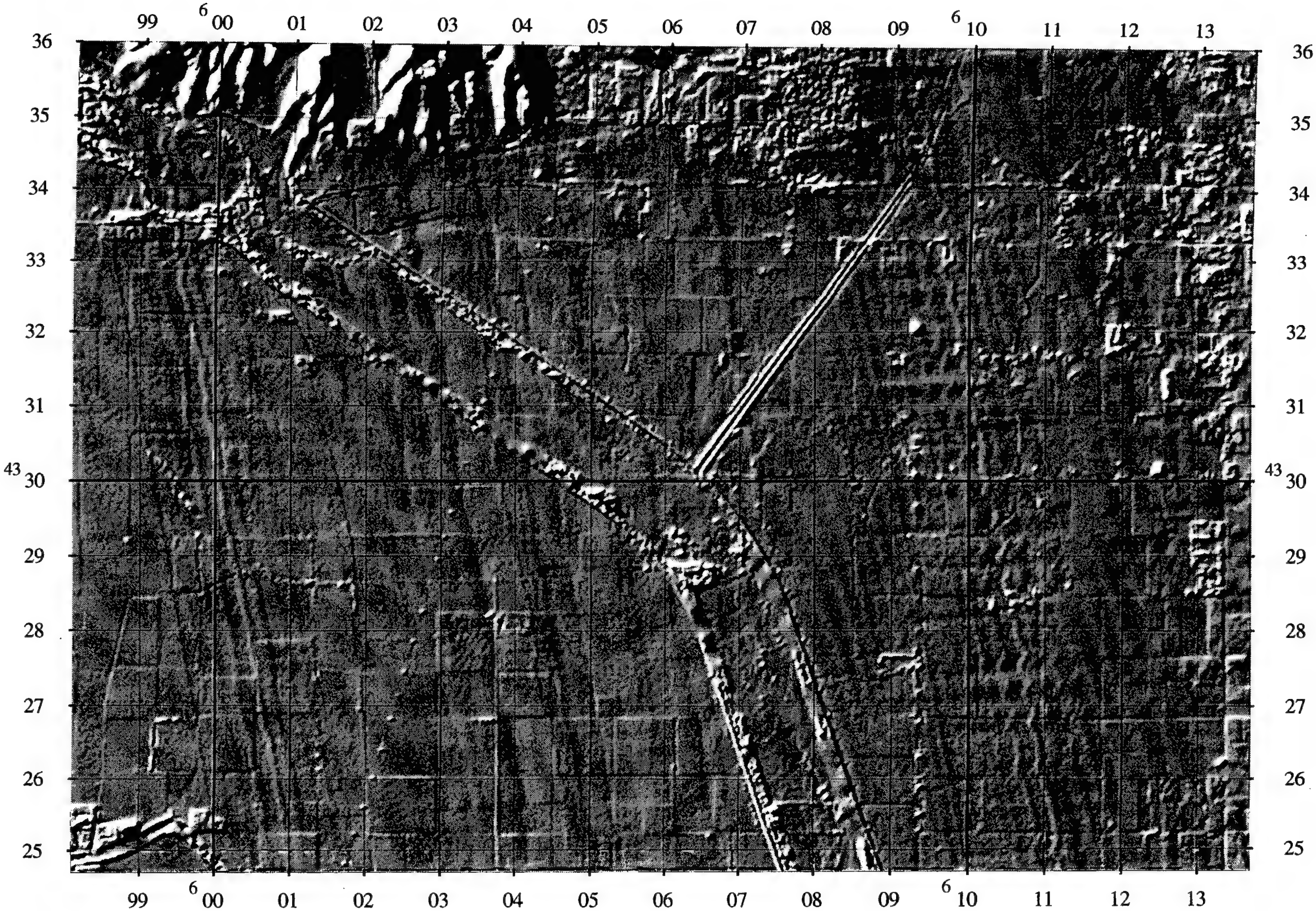

Figure 9. North to South and Water Anomalies

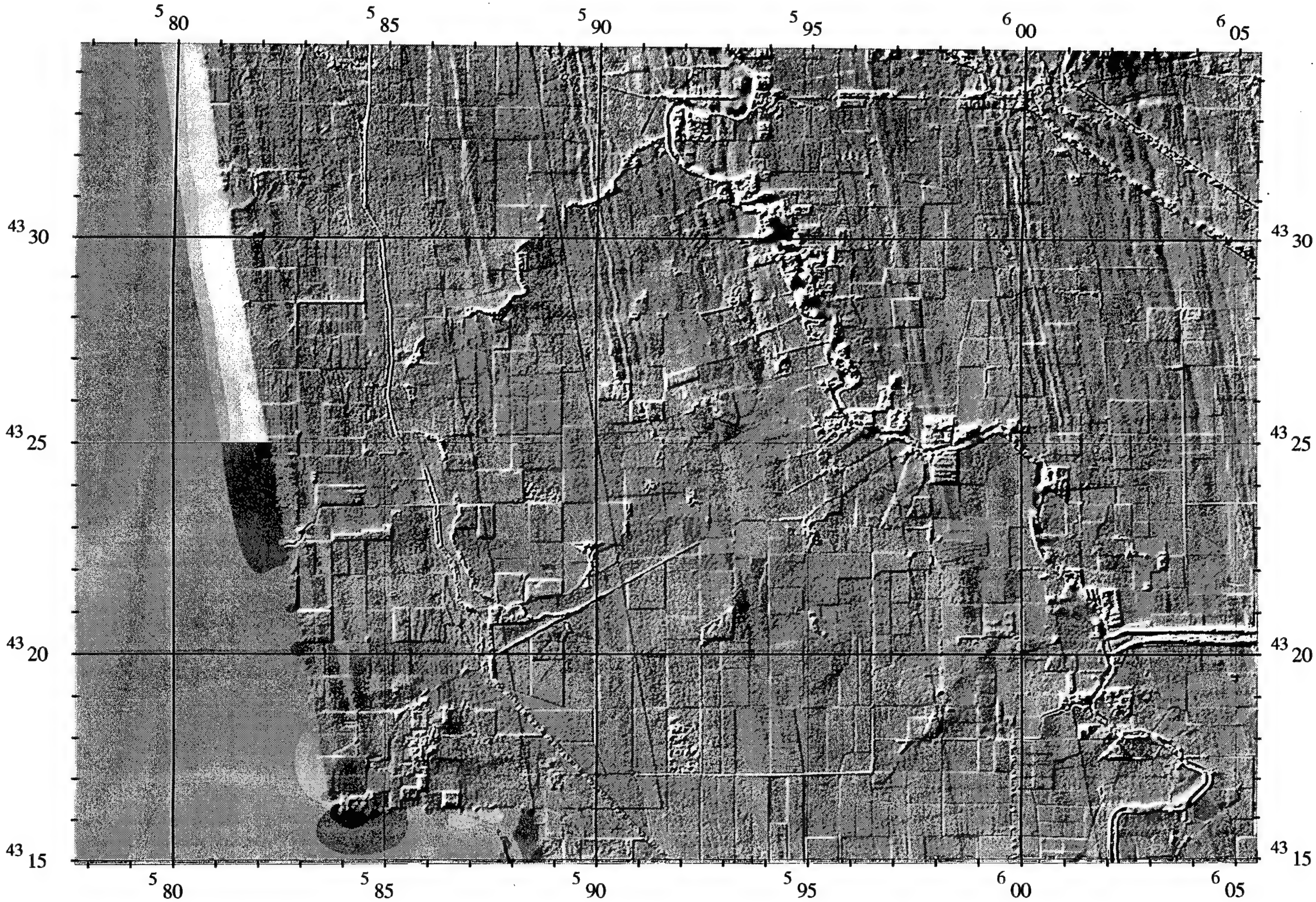

Figure 10. North to South and Water Anomalies

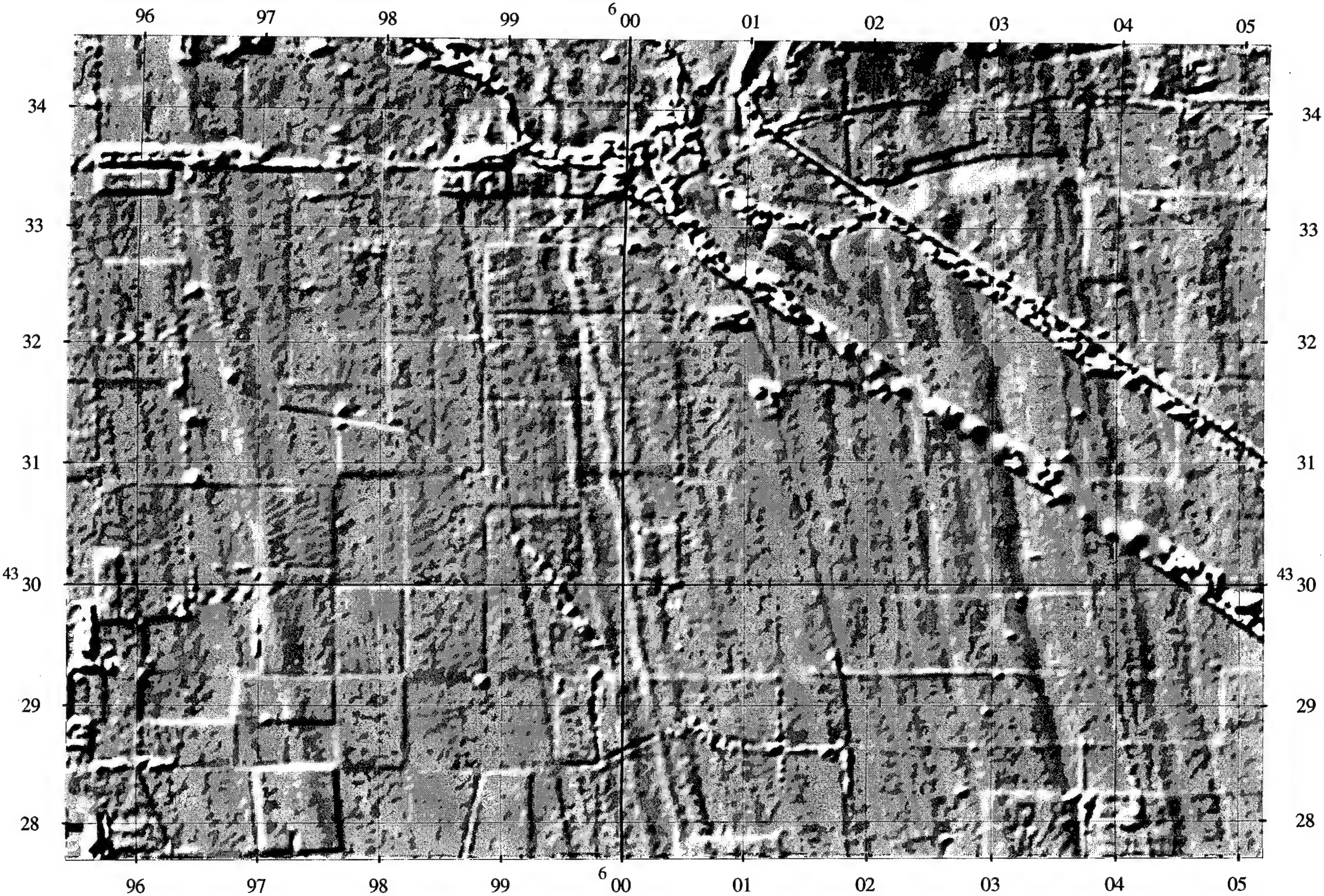

Figure 11. North to South and Water Anomalies

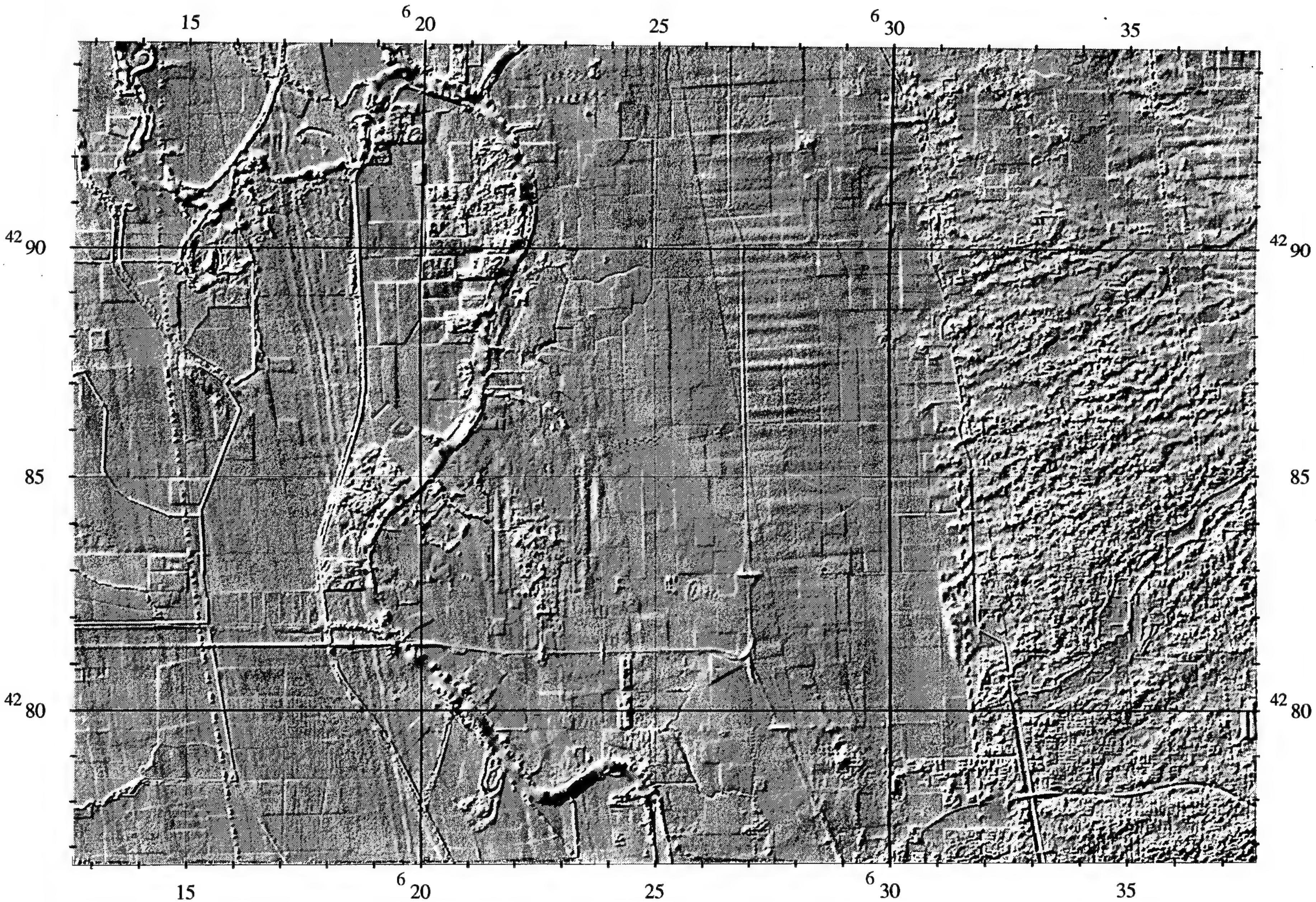

Figure 12. Motion Artifacts, North to South and Water Anomalies

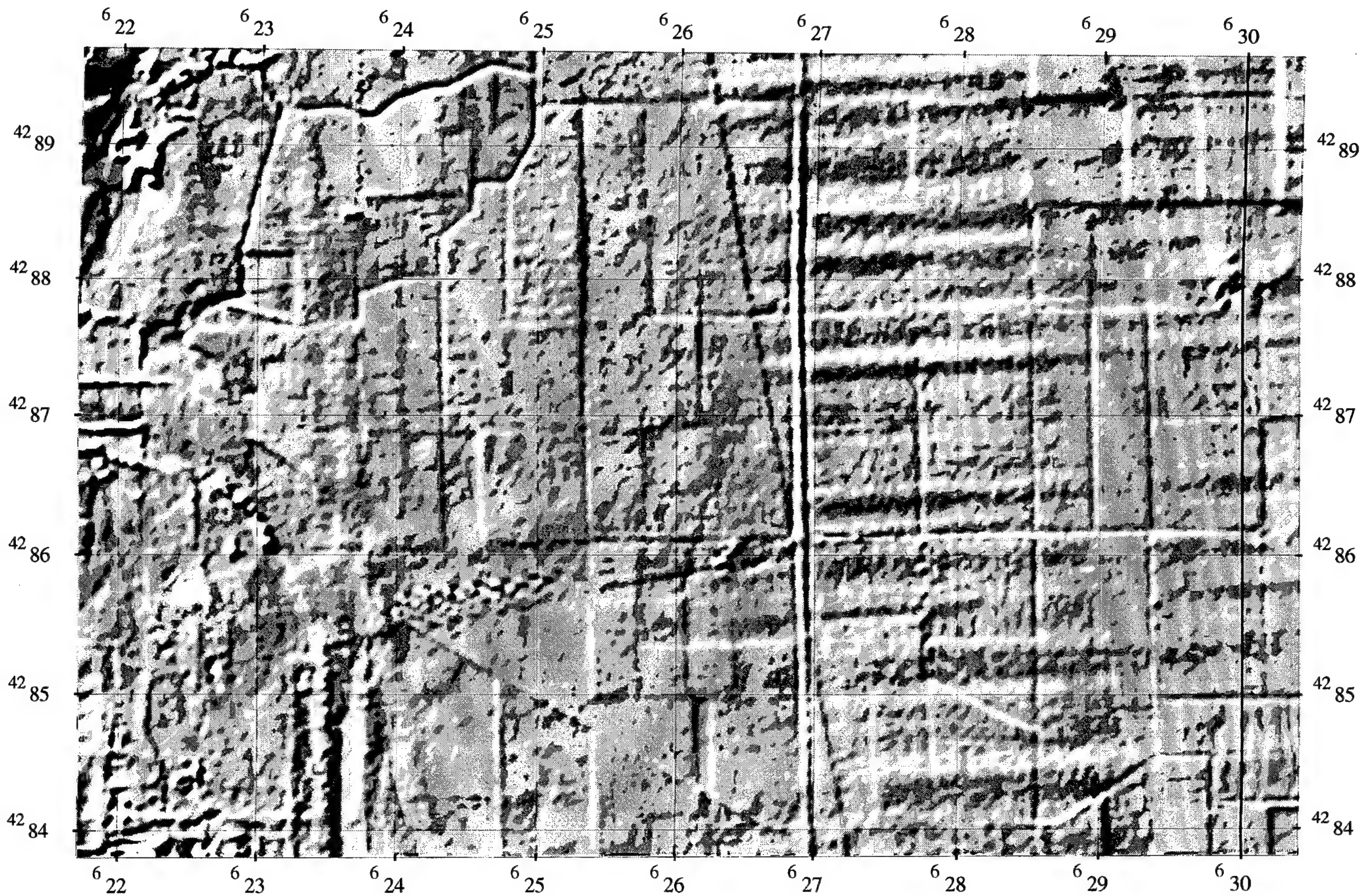

Figure 13. Zoomed in Area of Figure 12 Showing Motion Artifacts

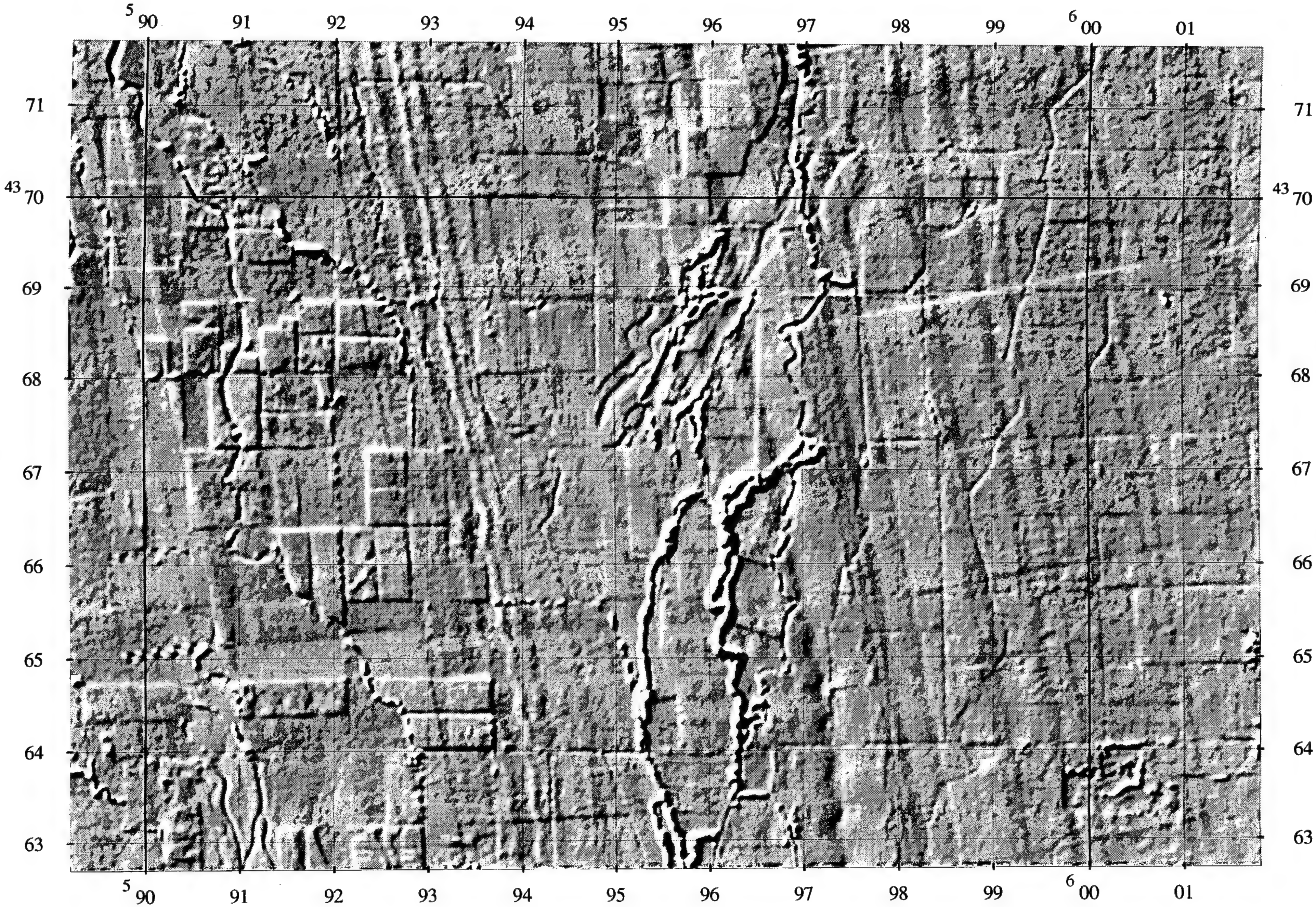

Figure 14. North to South Anomalies with Minor Motion Artifacts

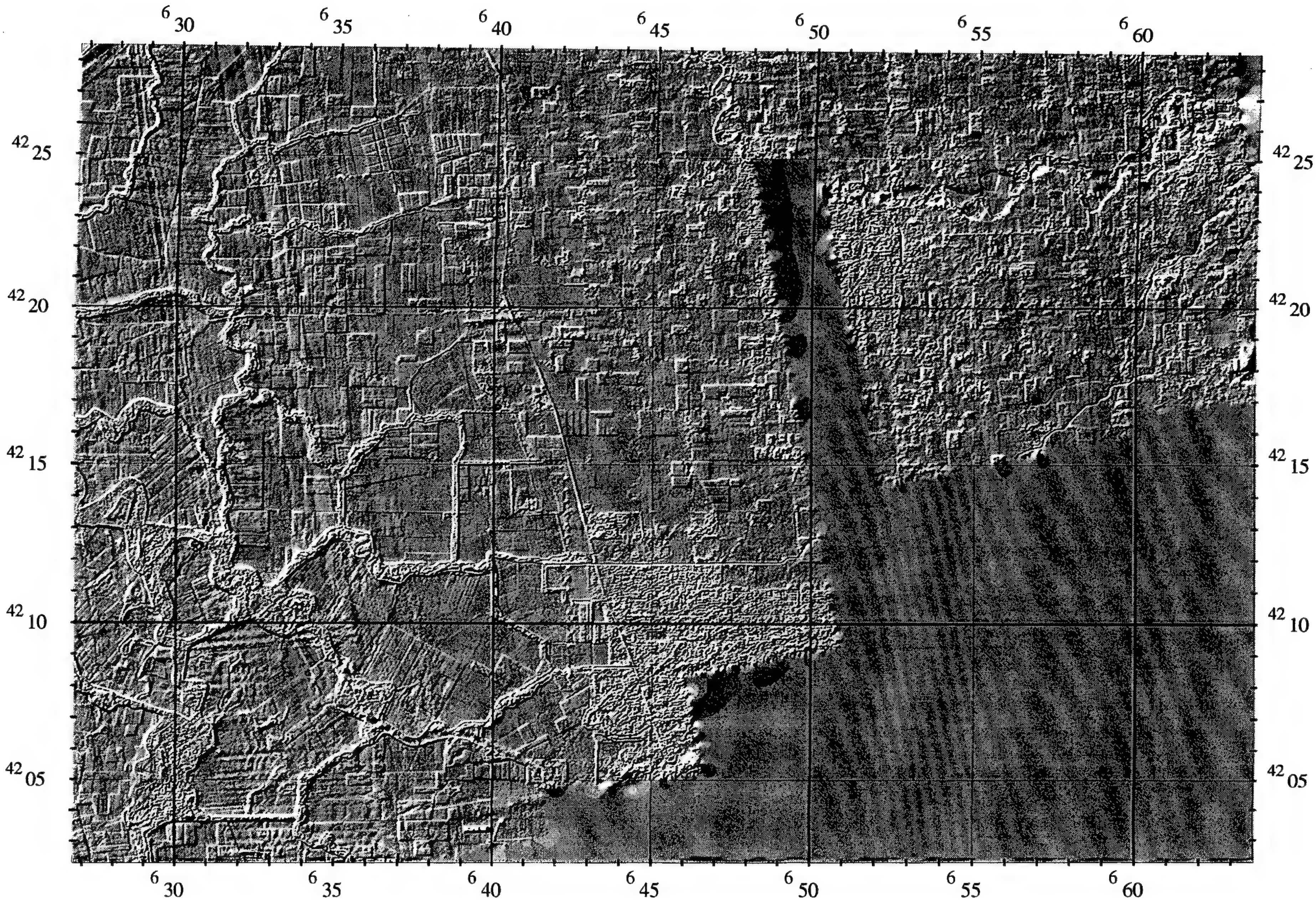

Figure 15. North to South Anomalies, Motion Artifacts, and Ghost Data

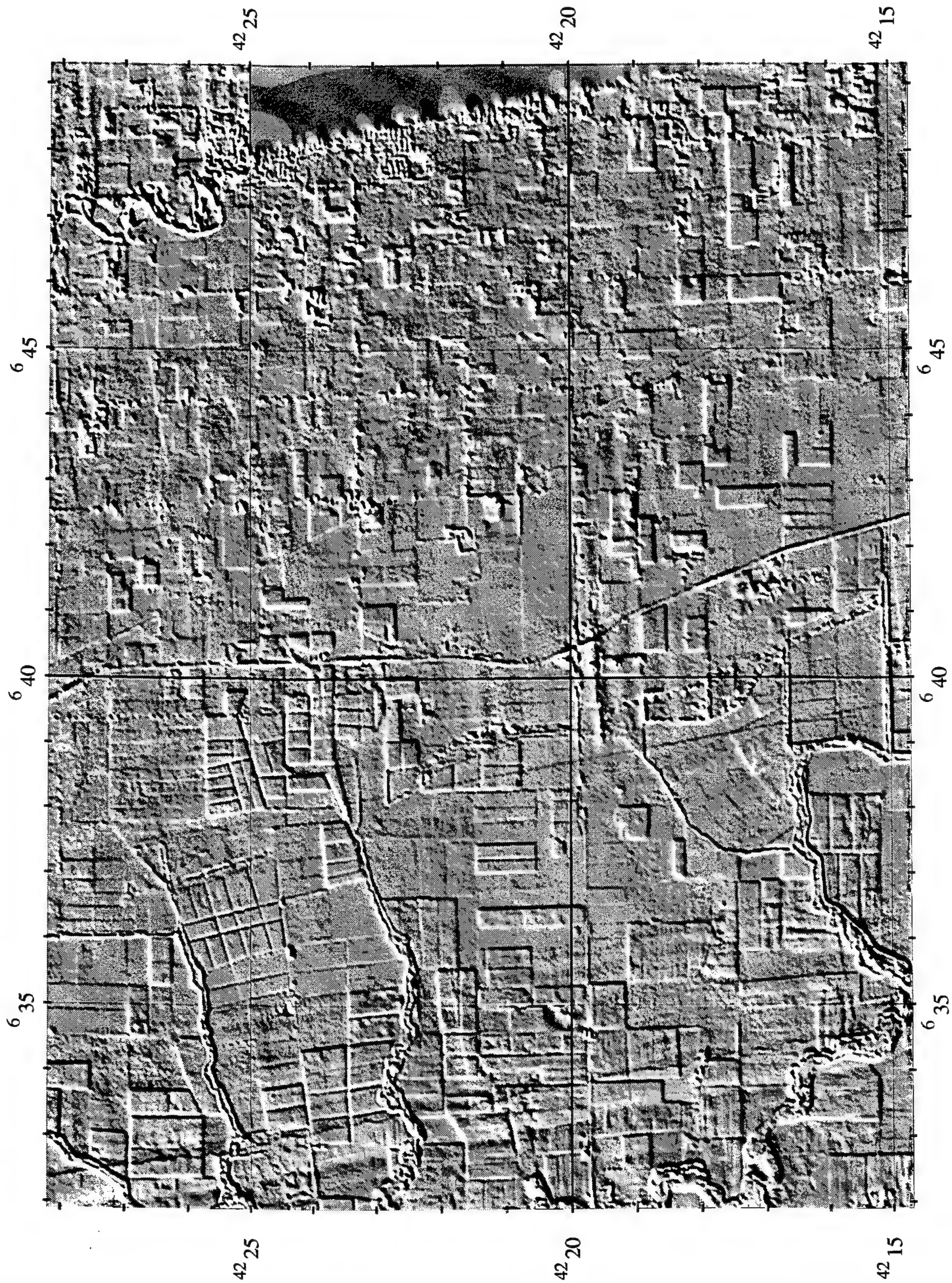

Figure 16. Zoomed in Area of Figure 15

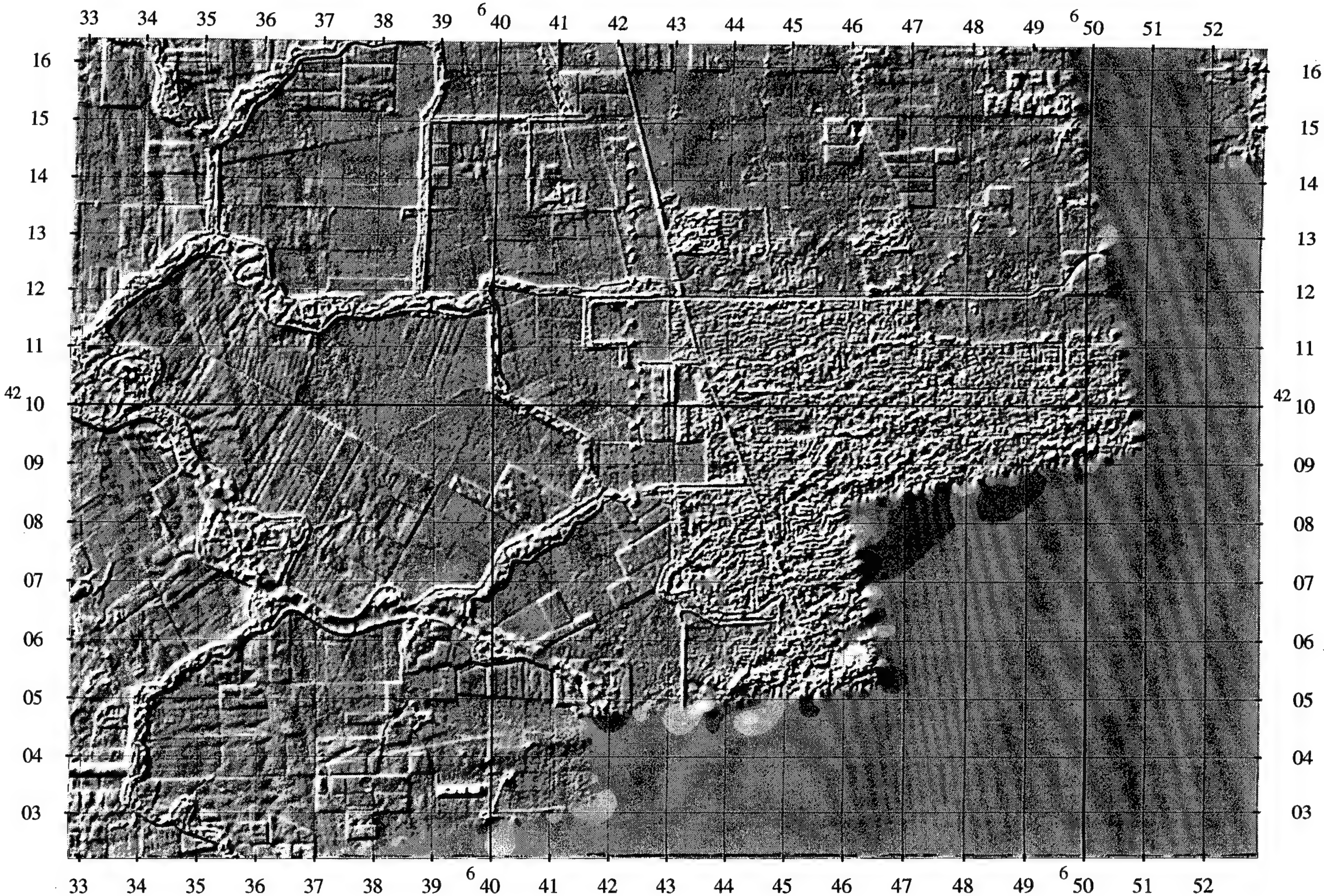

Figure 17. Zoomed in Area of Figure 15

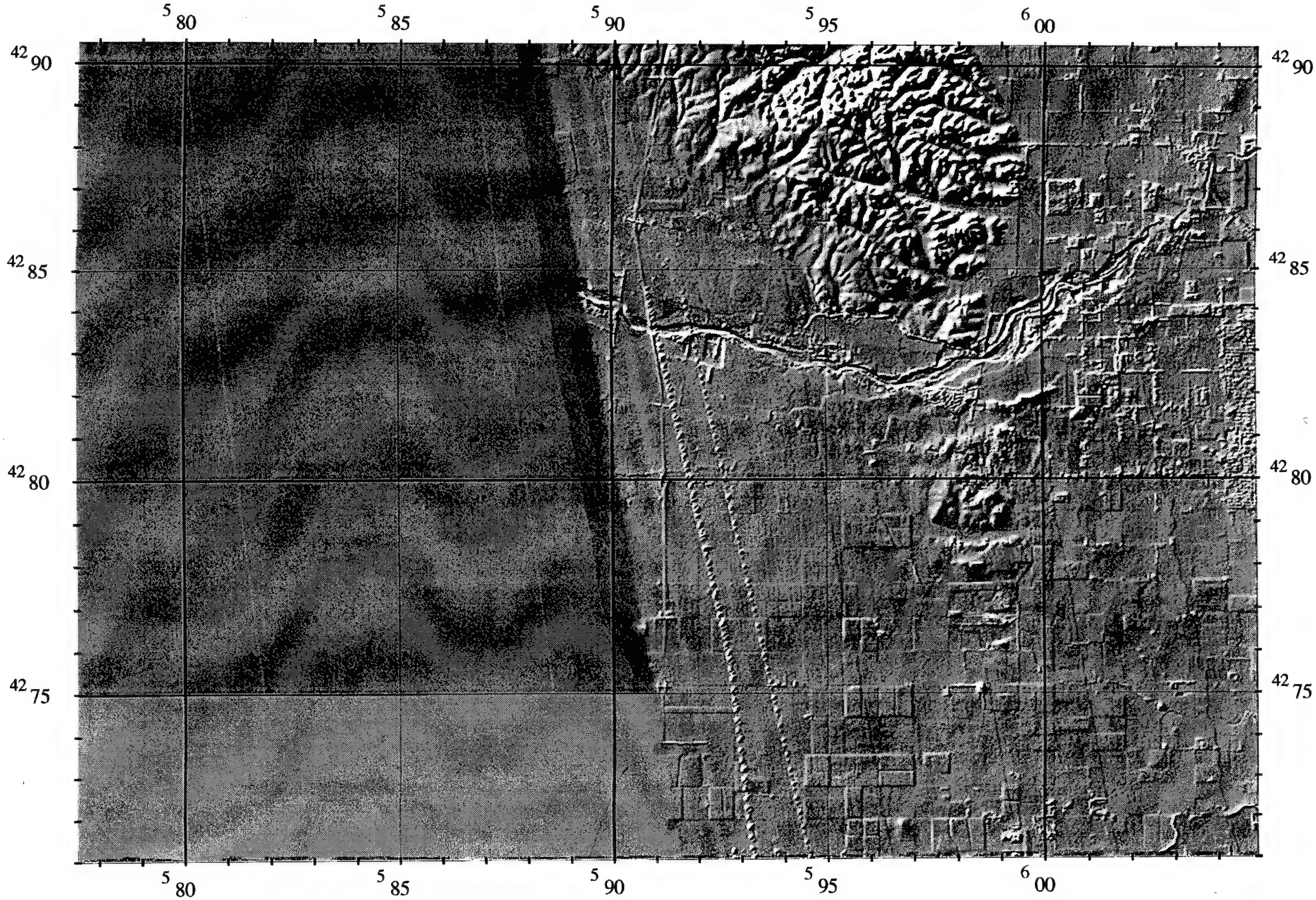

Figure 18. Ghost Data and North to South Anomalies

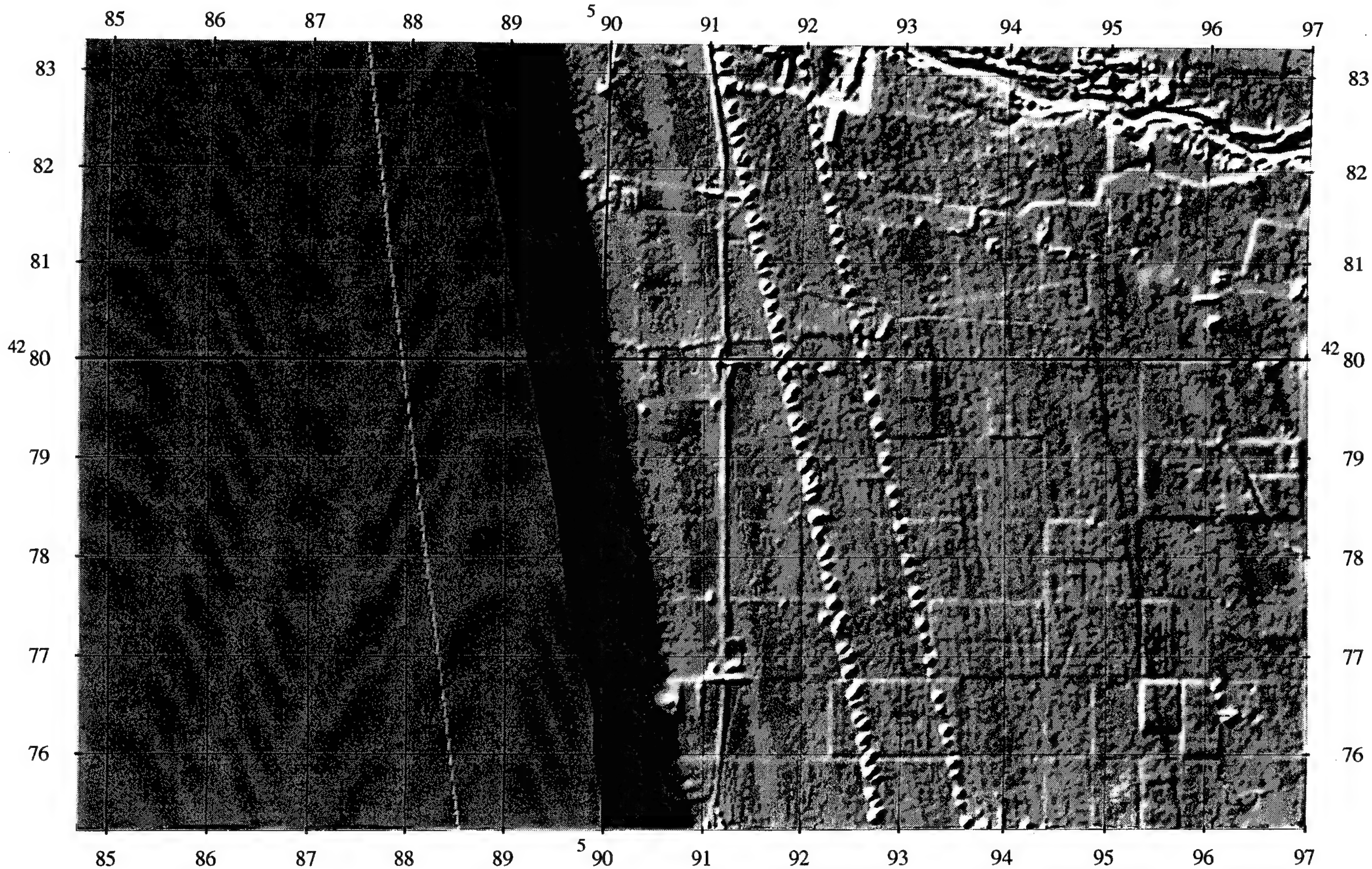

Figure 19. Zoomed in Area of Figure 18

THIRD PRODUCT DELIVERY

In Figure 20, a shaded relief is used to show the third delivery extent of the Intermap DEM and magnitude data sets with an approximate area of 8,596 mi^2 or 22,264 km^2. The Intermap magnitude data set had the same area as the DEM data set. The tiling scheme used was different from the second delivery. Intermap used an oversized 7.5-minute USGS quad tiling scheme. Intermap delivered a total of 153 files for each DEM and magnitude data set with header files. An example of the overlap in the Intermap DEM quads is shown in Figure 21 using DEM files 138121c5 and 138121c6. A README file was added to each CD-ROM for this delivery to clarify questions about each data set as requested by TEC and CalDoC. A copy of the README statement used for one DEM and magnitude CD-ROM is included in Appendices 1 and 2. The southern portion of the delivery extends into the northern area and is approximately one quarter of the second delivery. Quality control checks focused on the DEM data set and spot checks were performed on the magnitude data set. Other than contractual issues, there were no problems with the second delivery.

Data Formats

The third Intermap DEM data set had an IEEE floating point, 32-bit signed binary format with a 10-m post spacing and a .dem extension. A single DEM header file has the Intermap header parameters for file 136120e3.txt in Figure 22. Notice the elimination of the Geoid: NIMA-96 statement referenced in the second Intermap delivery. A full file listing of the delivered DEMs is shown in Figure 24 minus their extensions and header files.

136120e3.txt
136120E3.DEM
UTM ZONE 10 WGS84
upper left easting 734395
upper left northing 4056865
number of rows 1431
number of columns 1223
pixel size 10m
pixel origin center

Figure 22. Final Delivery DEM Header File

The third Intermap magnitude data set had an 8-bit BIL format with a 2.5-m resolution and a .mag extension. A single magnitude header file is shown with the Intermap header parameters for file 136120f1.txt in Figure 23. No statements are made to the number of bits in the magnitude data set, which is referenced in the README statement. A full file listing is shown in Figure 24 minus their file extensions for the magnitude data set. All header files had the same file names and .txt extensions, and precautions were taken to separate the two data sets.

Figure 20. Shaded Relief of North and South Deliveries

Figure 21. Overlap of Third Delivery DEMs (138121C5 and 138121C6)

File 136120F1.txt
UTM Zone 10   WGS84
upper left easting 756350.0
upper left northing 4071379.0
number of rows 5720
number of pixels 4888
pixel size 2.5m

Figure 23. Final Delivery Magnitude Image Header File

136119f8	137120b4	137121e3	138121a4	138121e2	138121h8	139122c1
136119g8	137120b5	137121e4	138121a5	138121e3	138122f1	139122d1
136120e3	137120b6	137121e5	138121a6	138121e4	138122g1	139122d2
136120f1	137120b7	137121f1	138121a7	138121e5	138122h1	
136120f2	137120b8	137121f2	138121b2	138121e6	139121a3	
136120f3	137120c4	137121f3	138121b3	138121e7	139121a4	
136120f4	137120c5	137121f4	138121b4	138121e8	139121a5	
136120g1	137120c6	137121f5	138121b5	138121f2	139121a6	
136120g2	137120c7	137121f6	138121b6	138121f3	139121a7	
136120g3	137120c8	137121g1	138121b7	138121f4	139121a8	
136120g4	137120d5	137121g2	138121b8	138121f5	139121b3	
136120g5	137120d6	137121g3	138121c2	138121f6	139121b4	
136120h1	137120d7	137121g4	138121c3	138121f7	139121b5	
136120h2	137120d8	137121g5	138121c4	138121f8	139121b6	
136120h3	137120e6	137121g6	138121c5	138121g3	139121b7	
136120h4	137120e7	137121g7	138121c6	138121g4	139121b8	
136120h5	137120e8	137121h1	138121c7	138121g5	139121c4	
136120h6	137120f7	137121h2	138121c8	138121g6	139121c5	
137120a2	137120f8	137121h3	138121d2	138121g7	139121c6	
137120a3	137120g8	137121h4	138121d3	138121g8	139121c7	
137120a4	137121c1	137121h5	138121d4	138121h3	139121c8	
137120a5	137121d1	137121h6	138121d5	138121h4	139121d7	
137120a6	137121d2	137121h7	138121d6	138121h5	139121d8	
137120a7	137121e1	138121a2	138121d7	138121h6	139122a1	
137120b3	137121e2	138121a3	138121d8	138121h7	139122b1	

Figure 24. File Listing for Final Product Delivery

DEM Anomalies

There were two major anomalies associated with the third Intermap DEM delivery. The areas used to illustrate the various anomalies of the third delivery for this report are shown in Figure 25. The first anomaly can be characterized as a motion artifact caused by the turbulence of the aircraft in flight. The second anomaly can be characterized as a merging artifact produced in the production of the DEM. The minor anomalies associated with the second delivery can still be found but were diminished or reduced in severity by the new calibration. Figure 25 indexes the images evaluated for the third delivery. Figures 26 through 42 display the improved resolution achieved by the contractor who was reprocessing the data. Many of the anomalies and artifacts introduced by production errors were successfully removed. After reprocessing and delivery of the third data set, some motion artifacts remained (as represented in the data). Note the marked improvements when comparing the corresponding images from the second delivery to the third delivery (Figures 29 through 35, 37, 41, and 42).

In Figure 26, the motion artifacts are shown following three flight lines and extending throughout the entire southern collection at varying elevation heights. In Figures 27 and 28, the same zoomed-in area displays the motion artifacts. The motion artifacts are displayed following two flight lines in Figure 29 starting near the western edge of the southern collection. A zoomed-in view of the motion artifact is shown in Figure 30. The second delivery anomalies are reduced in severity as seen in Figure 31 and a zoomed-in view of the same area is displayed in Figure 32. More anomalies associated with the second delivery are shown in Figures 33 through 35 and are an improvement over the second DEM delivery. In Figures 36 through 40, a mixture of motion artifacts with the merging anomalies is displayed. The merging anomalies range in value up to 1 m in height. In Figures 41 and 42, water anomalies from the second delivery are gone.

Profiling was used to check and view the motion artifact's vertical height. All motion artifacts were below the stated tolerance for the DEM data set. Arc/Info was used for the final DEM data sets to import, export, and UNIX compress to test the operational use of the data. Most of the DEM data sets passed without problems. The following nine DEM files would not compress due to elevation values not repeating: 137121e3, 137121e4, 137121e5, 137121f5, 137121f6, 137121g6, 137121g7, 137121h7, and 138122f1. The following two DEM files, 136119f8 and 136119g8, were delivered in UTM zone 11 for the third product delivery. The two DEM files, 136119f8 and 136119g8, were corrected to UTM zone 10 to match the 151 DEM files delivered in UTM zone 10 for the third delivery.

VERTICAL ACCURACY

The main goal of the vertical accuracy assessment is to establish the relative accuracy of the Intermap DEM delivery. The test area will be an approximate 23 km by 56 km area shown in Figure 43. This area is comprised of six Intermap DEM files: 138121b5, 138121b6, 138121c5, 138121c6, 138121d5, and 138121e5. These six DEM files were used to support a ground survey study conducted by Mr. Dave Kehrlein, California Office of Emergency Services (OES).

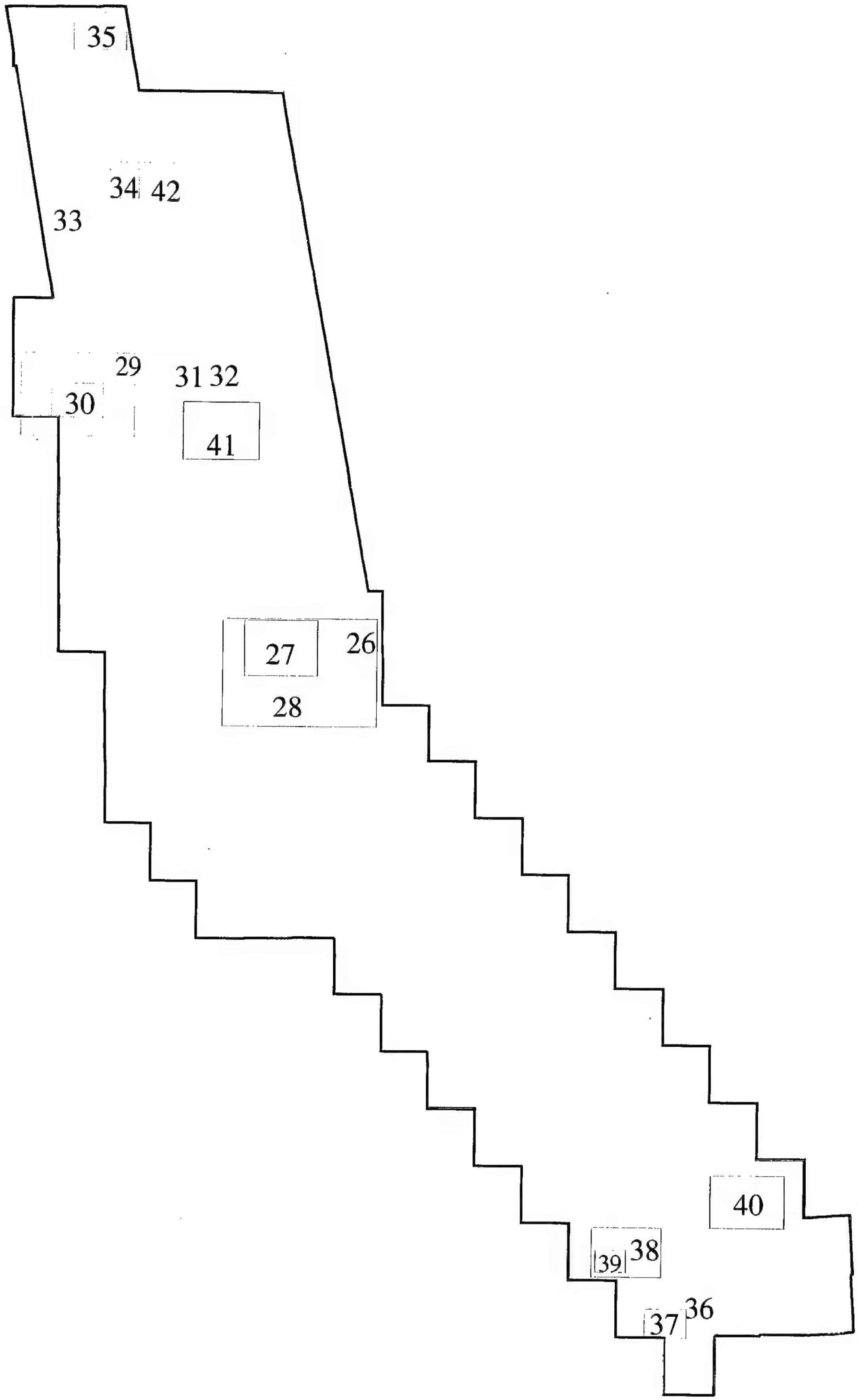

Figure 25. Location of Shaded Reliefs by Figure Number

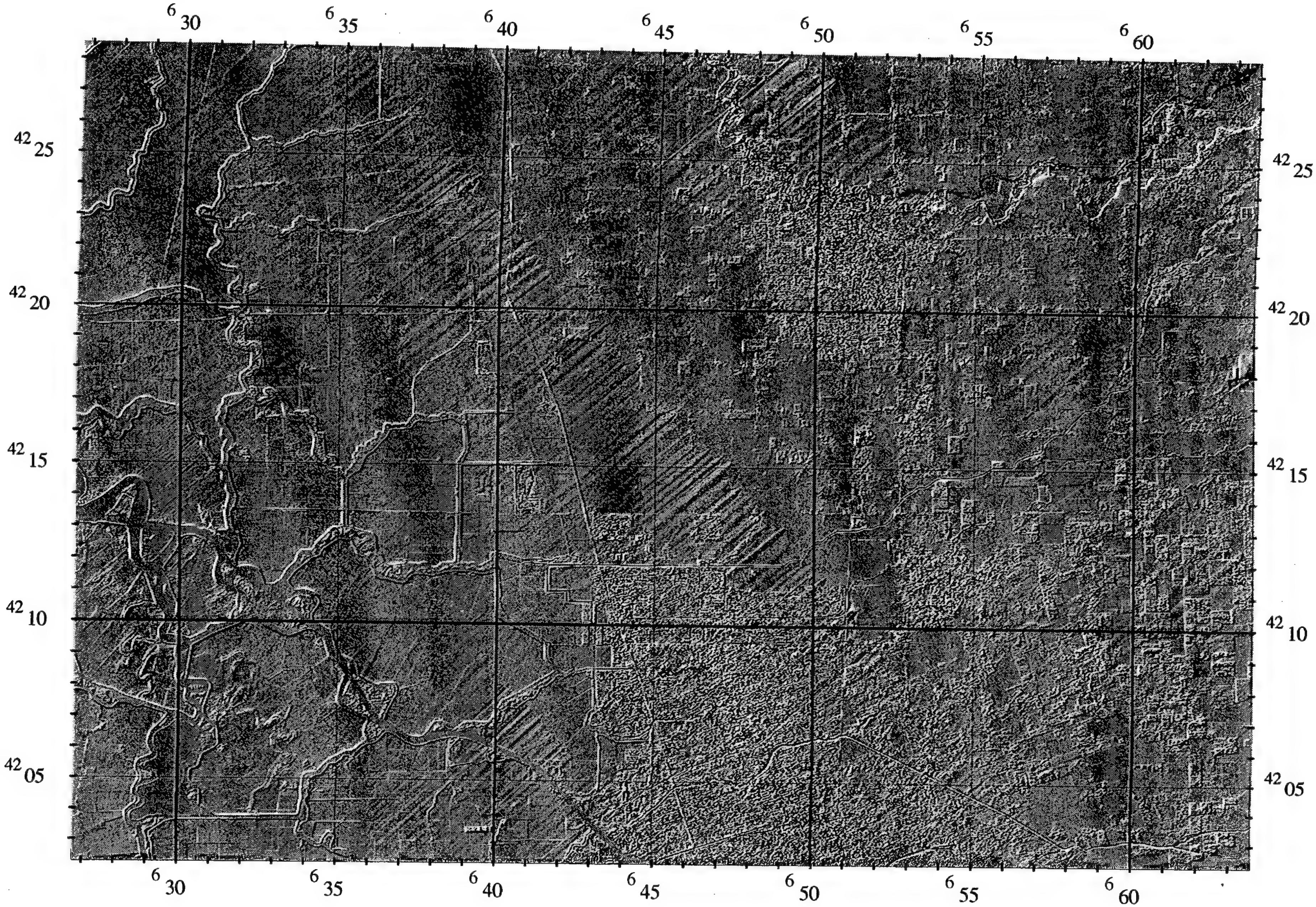

Figure 26. Motion Artifacts

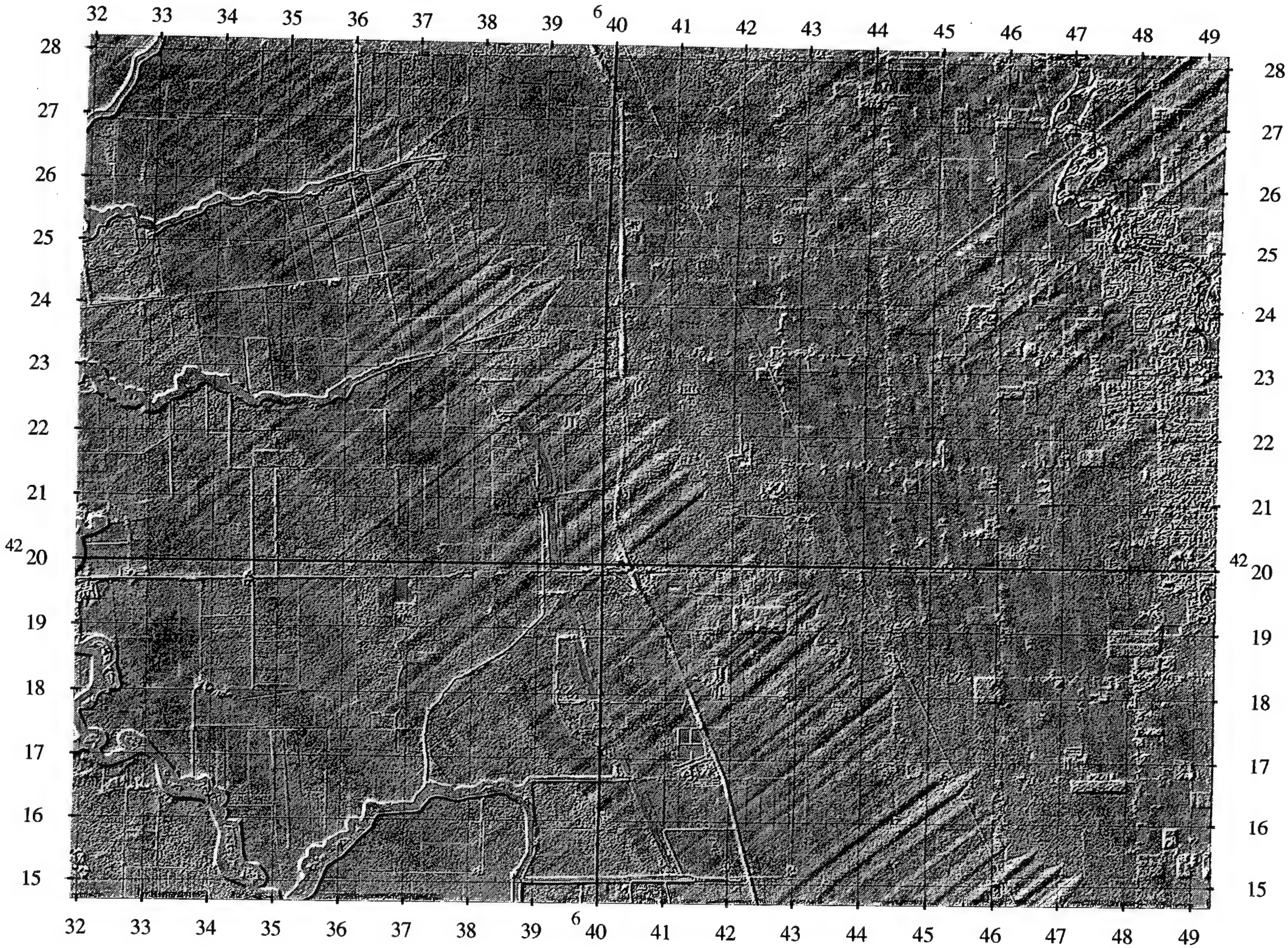

Figure 27. Zoomed In Area of Figure 26

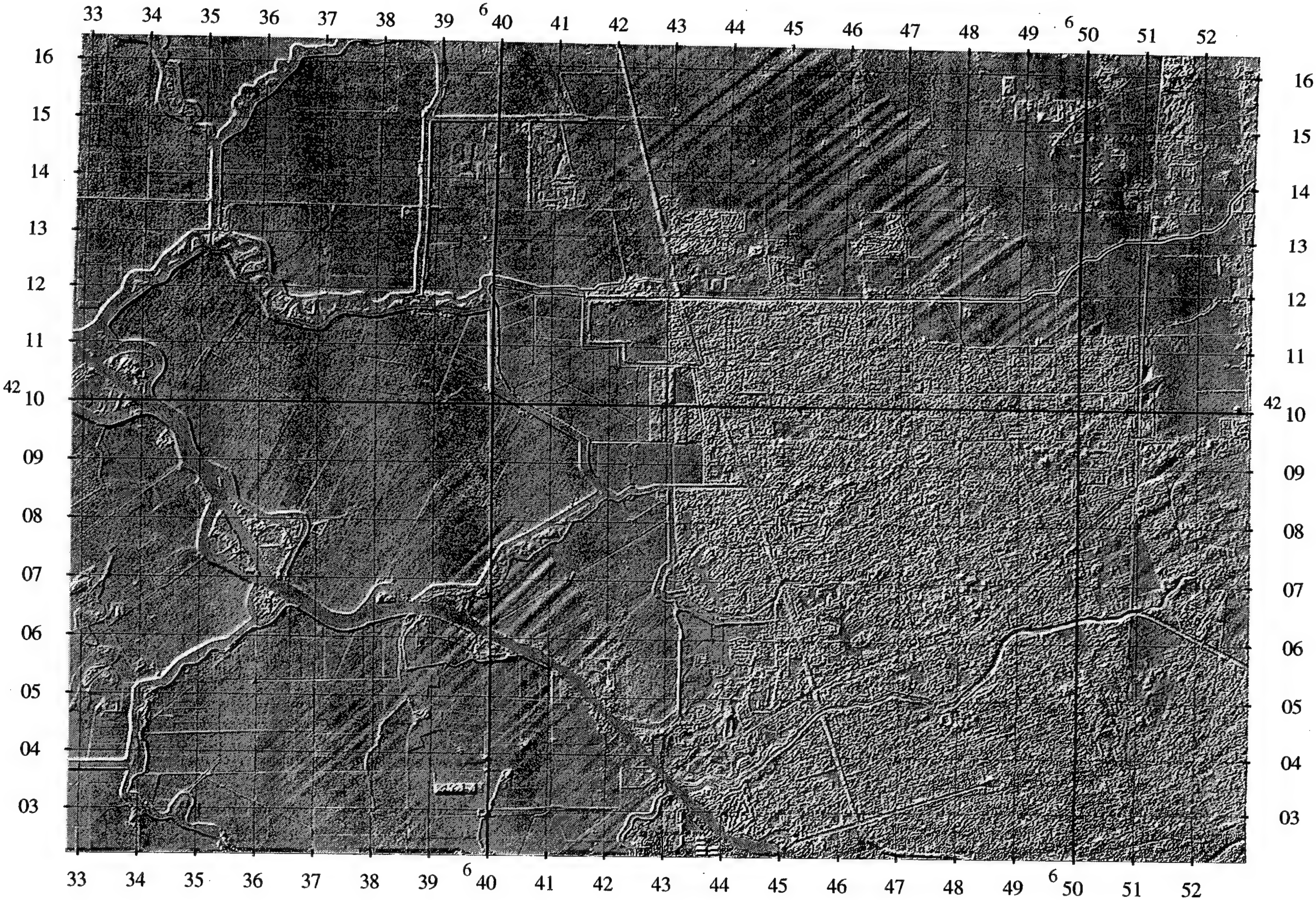

Figure 28. Zoomed In Area of Figure 26

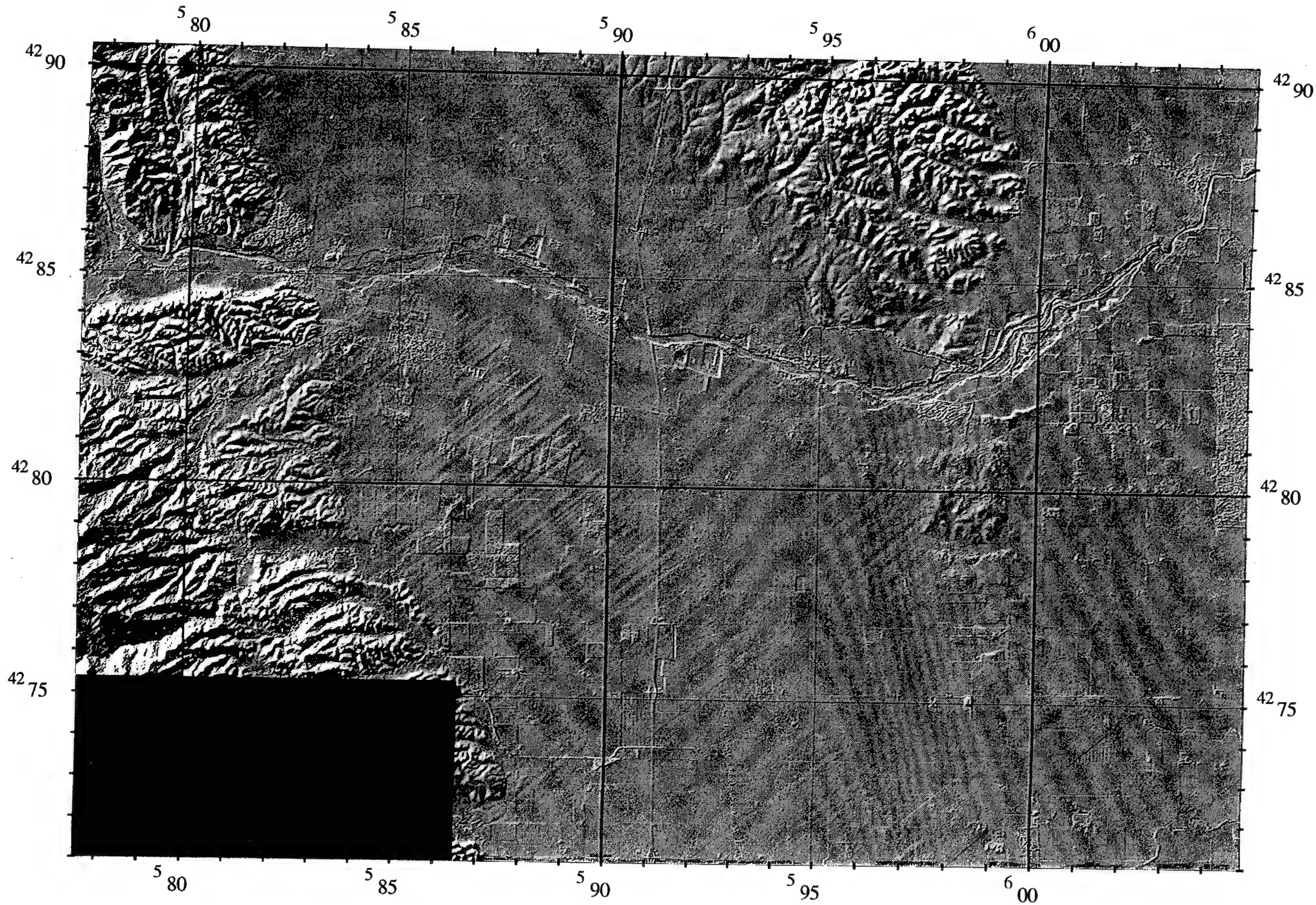

Figure 29. Motion Artifacts, see Figure 18 to Compare

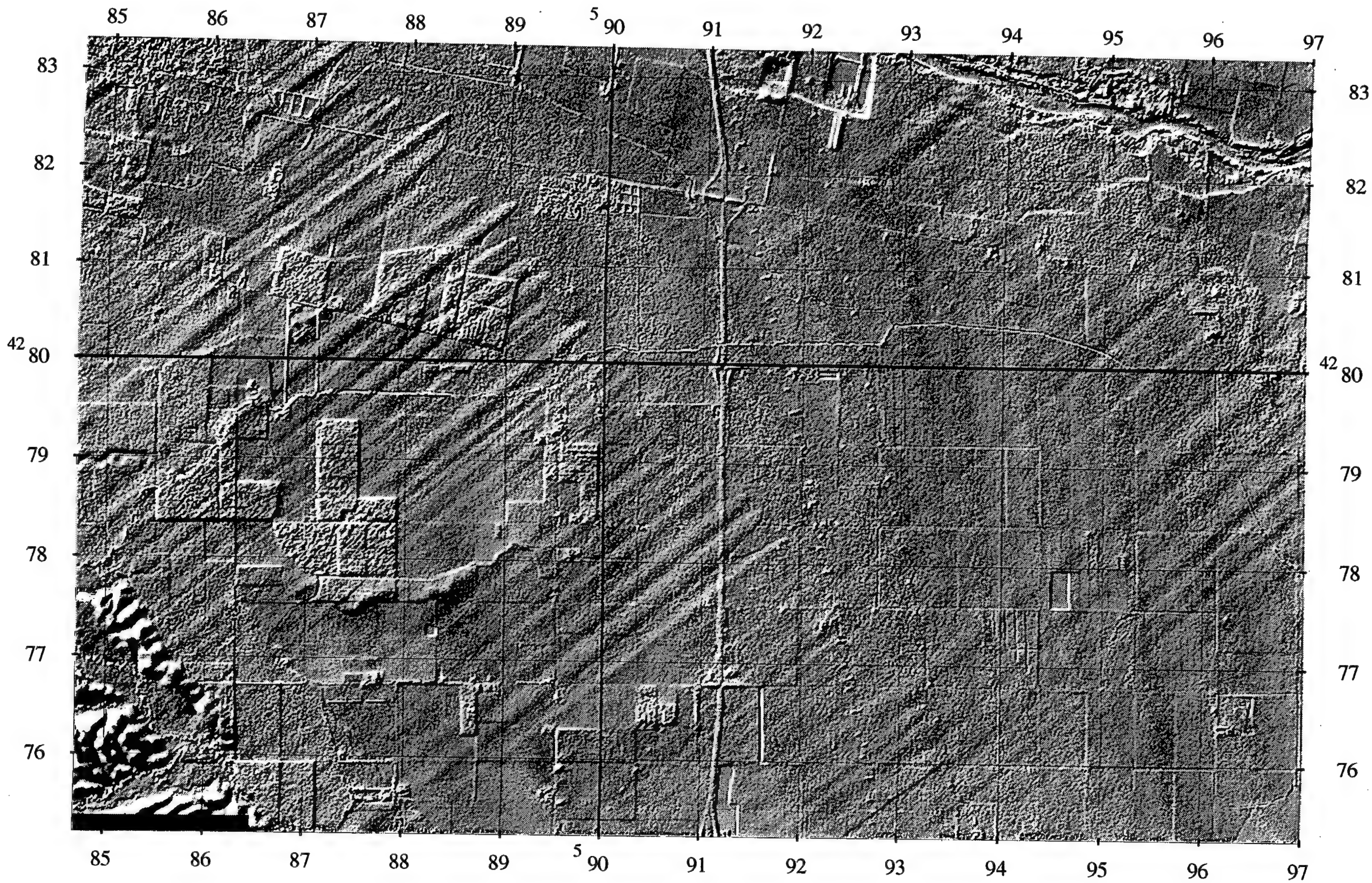

Figure 30. Zoomed In Area of Figure 29, see Figure 19 to Compare

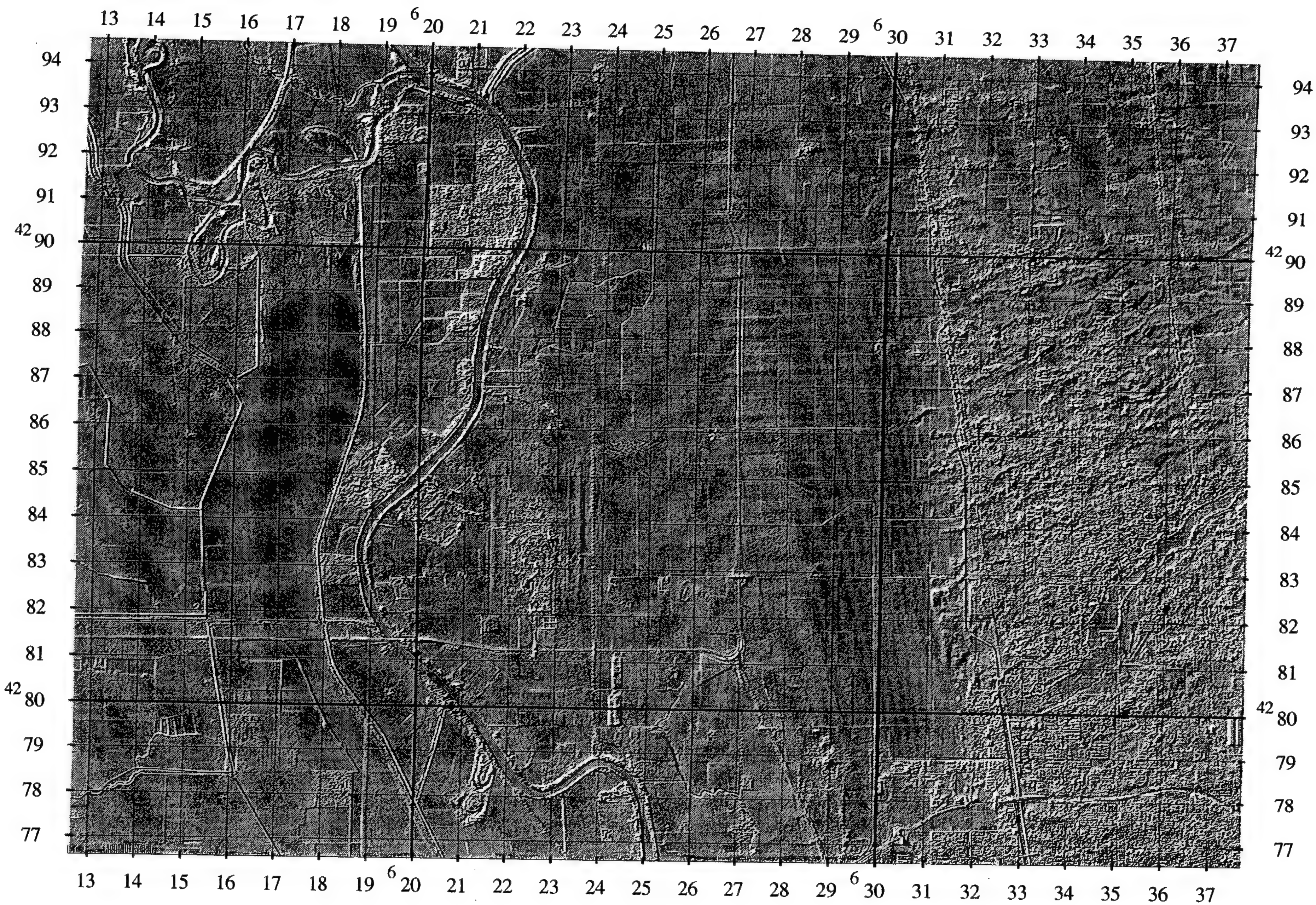

Figure 31. Diminished Anomalies, see Figure 12 to Compare

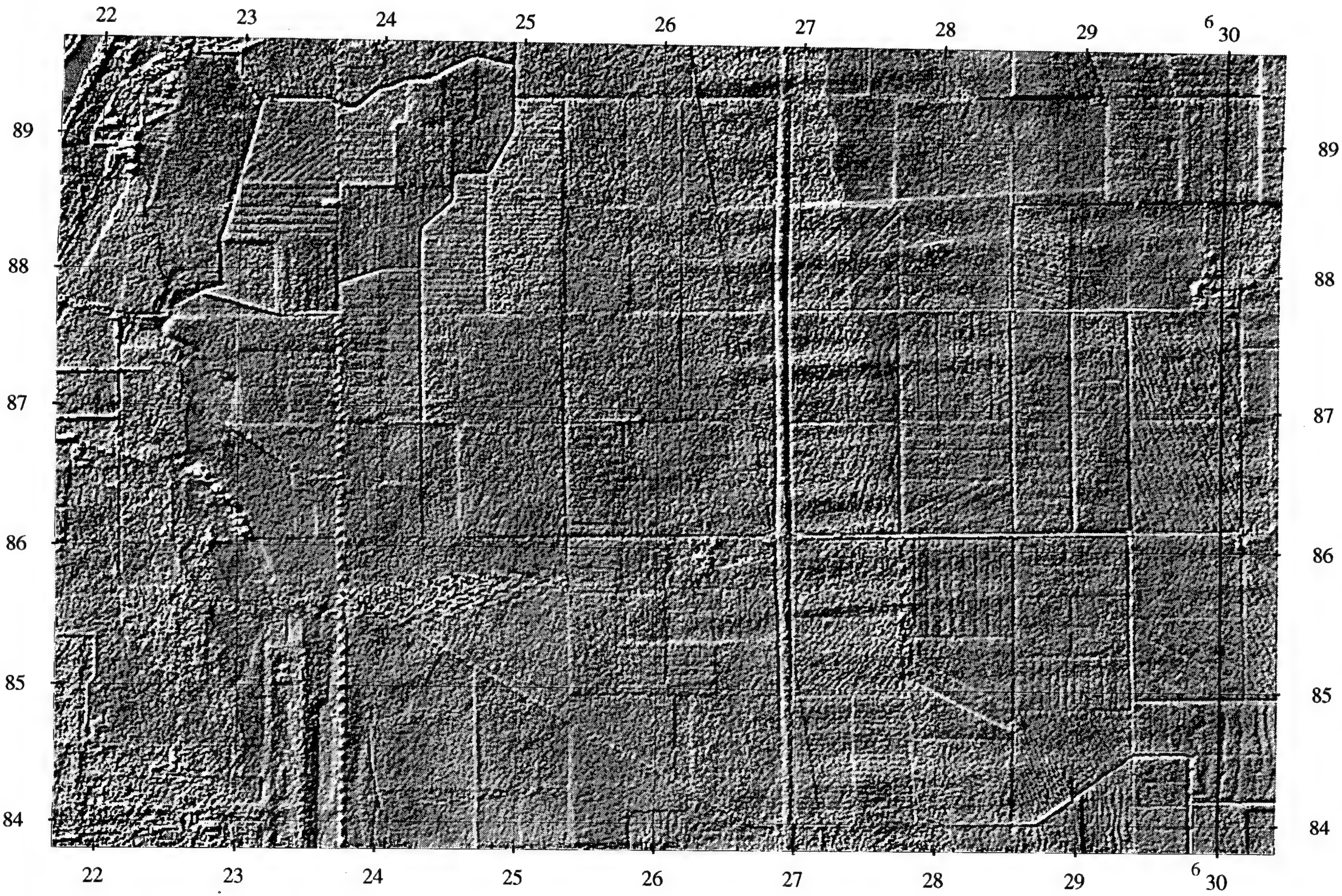

Figure 32. Diminished Anomalies, see Figure 13 to Compare

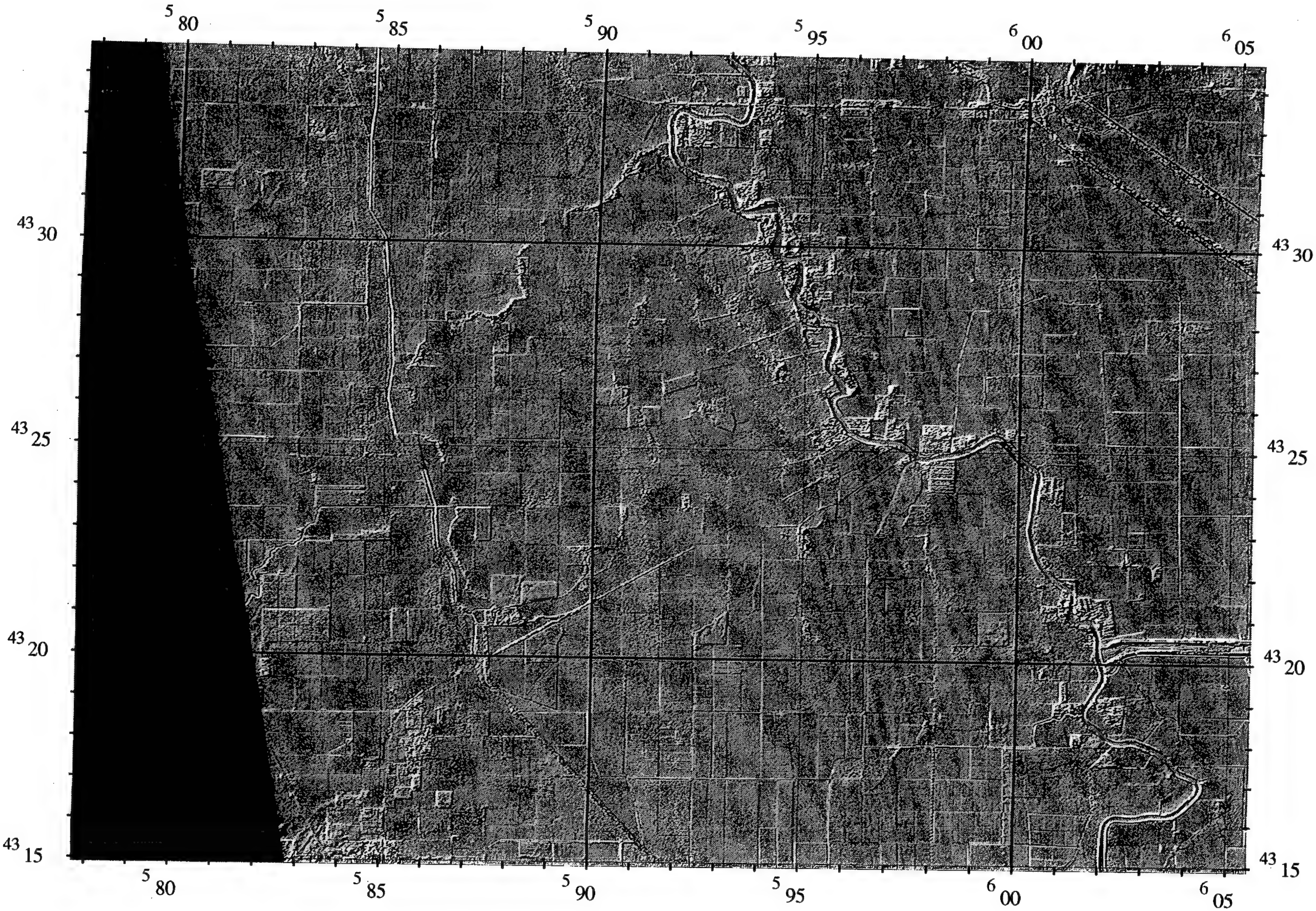

Figure 33. Diminished Anomalies, see Figure 10 to Compare

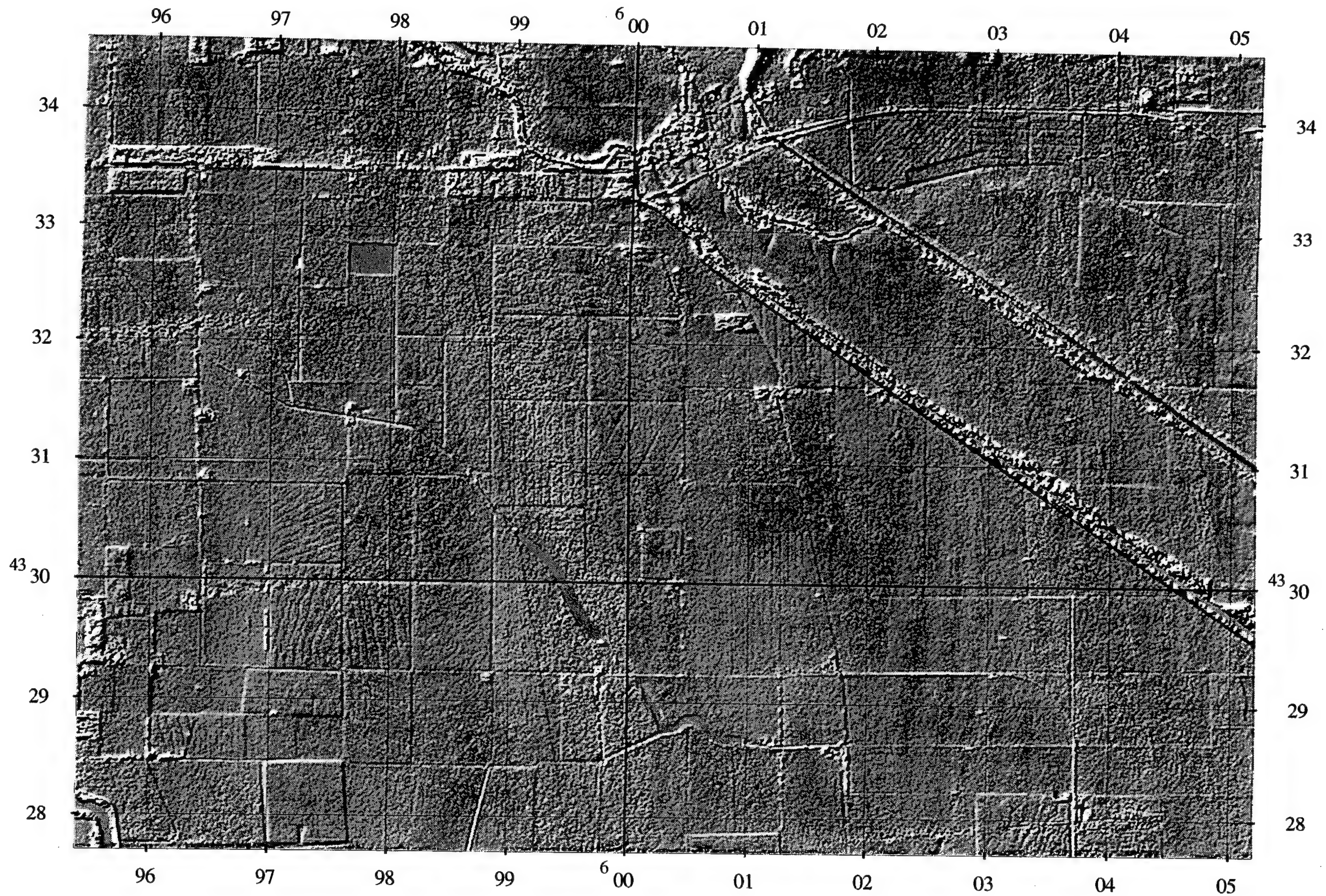

Figure 34. Diminished Anomalies, see Figure 11 to Compare

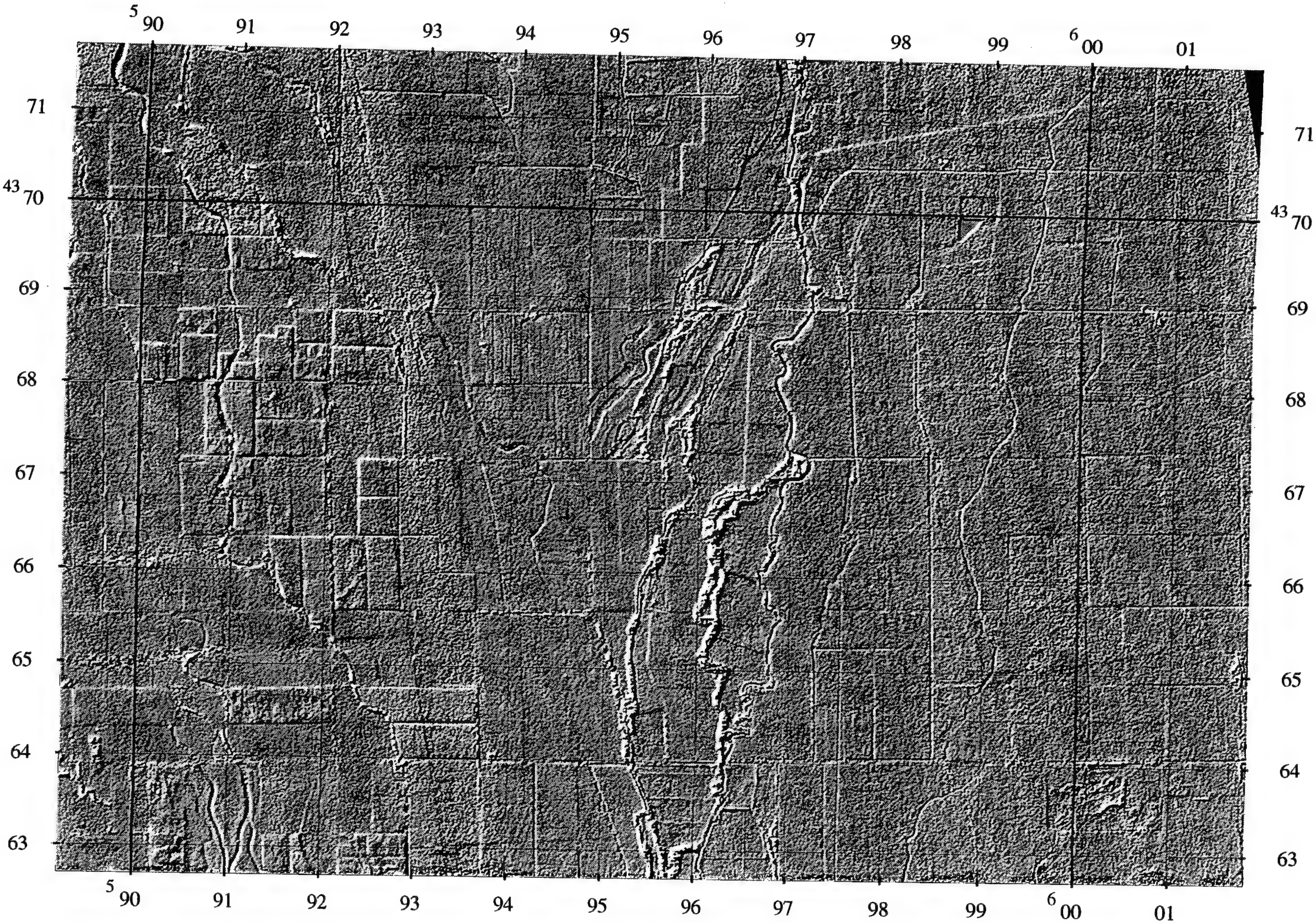

Figure 35. Diminished Anomalies, see Figure 14 to Compare

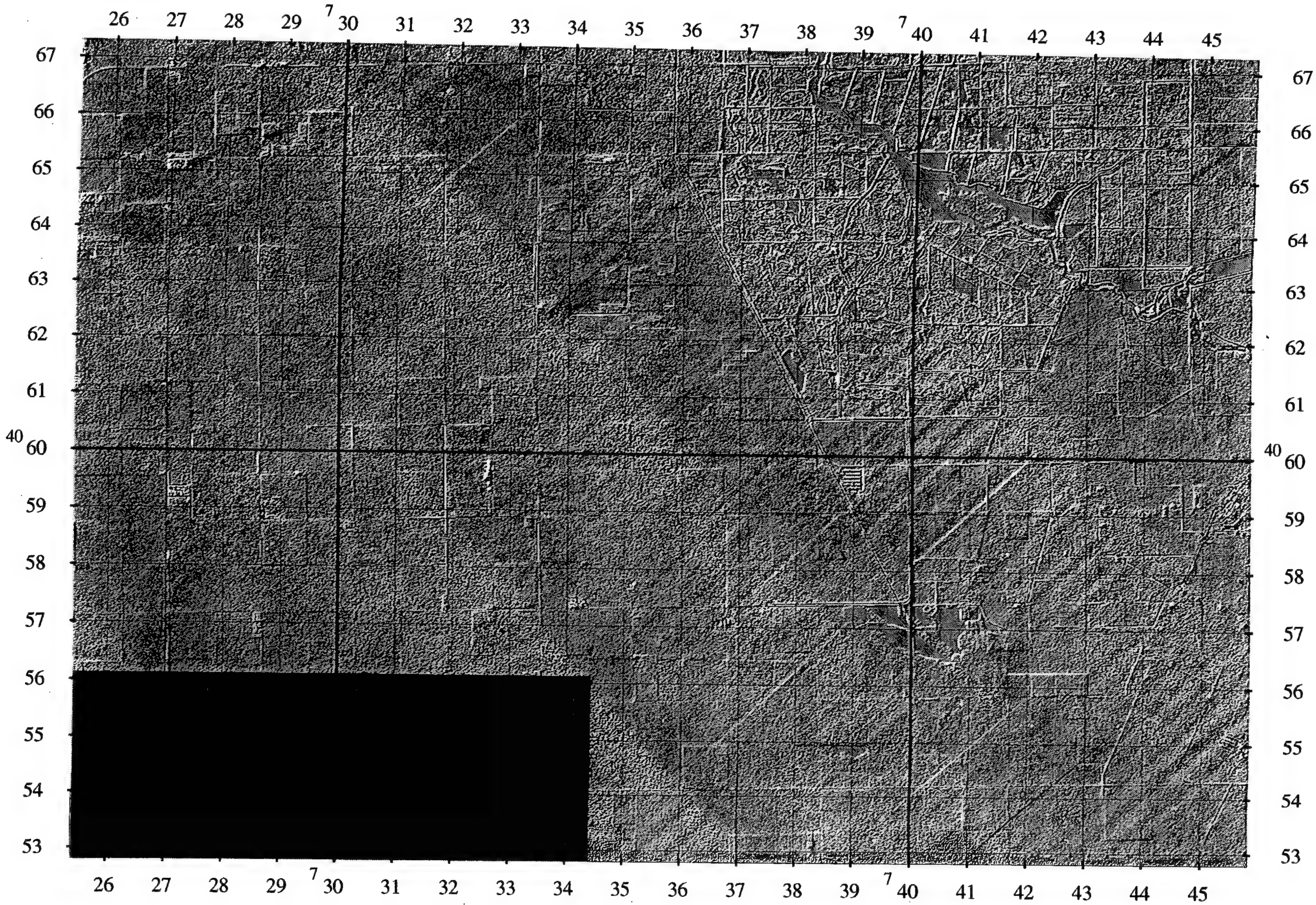

Figure 36. Merging and Motion Artifacts

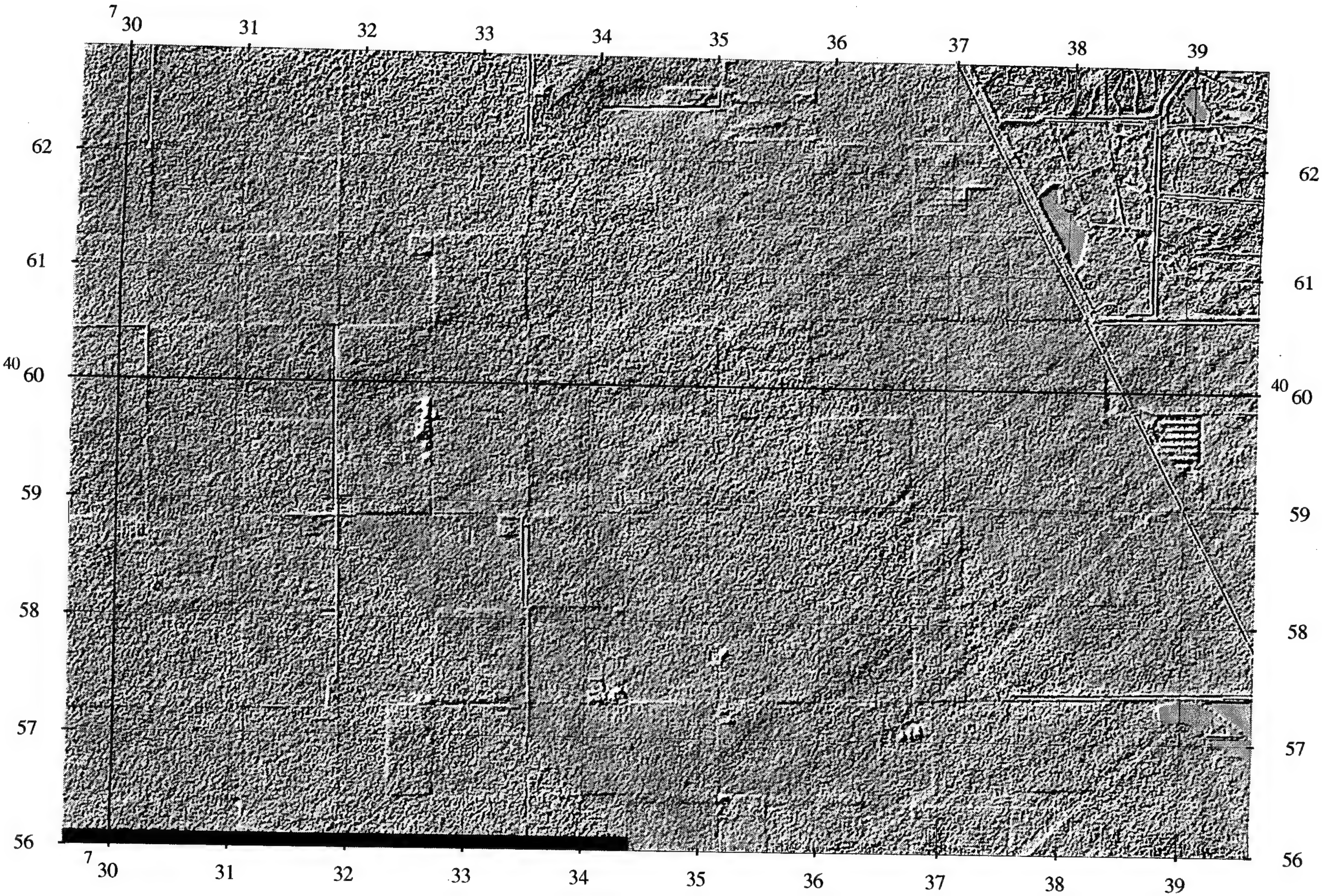

Figure 37. Zoomed In Area of Figure 36

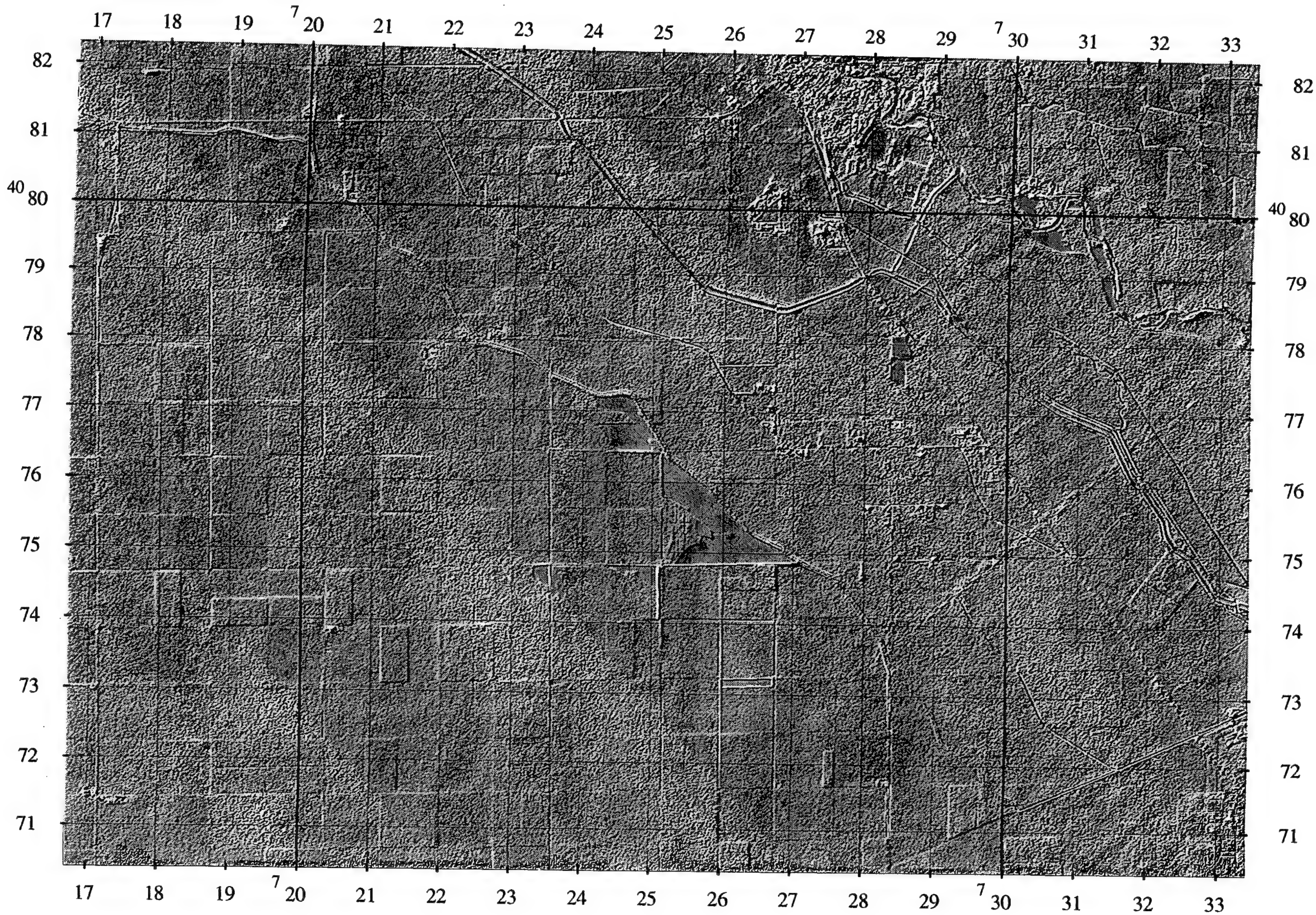

Figure 38. Merging and Motion Artifacts

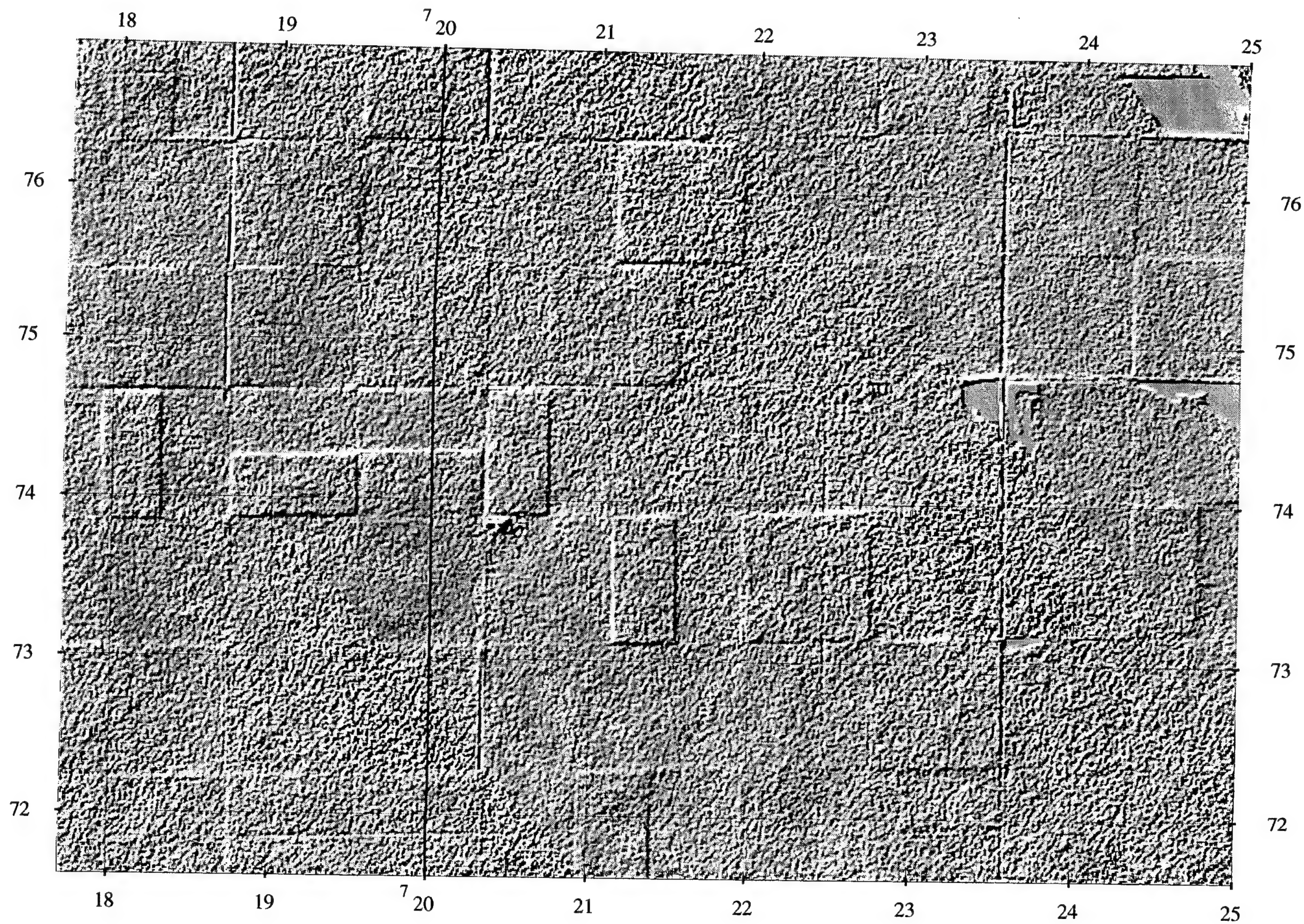

Figure 39. Zoomed in Area of Figure 38

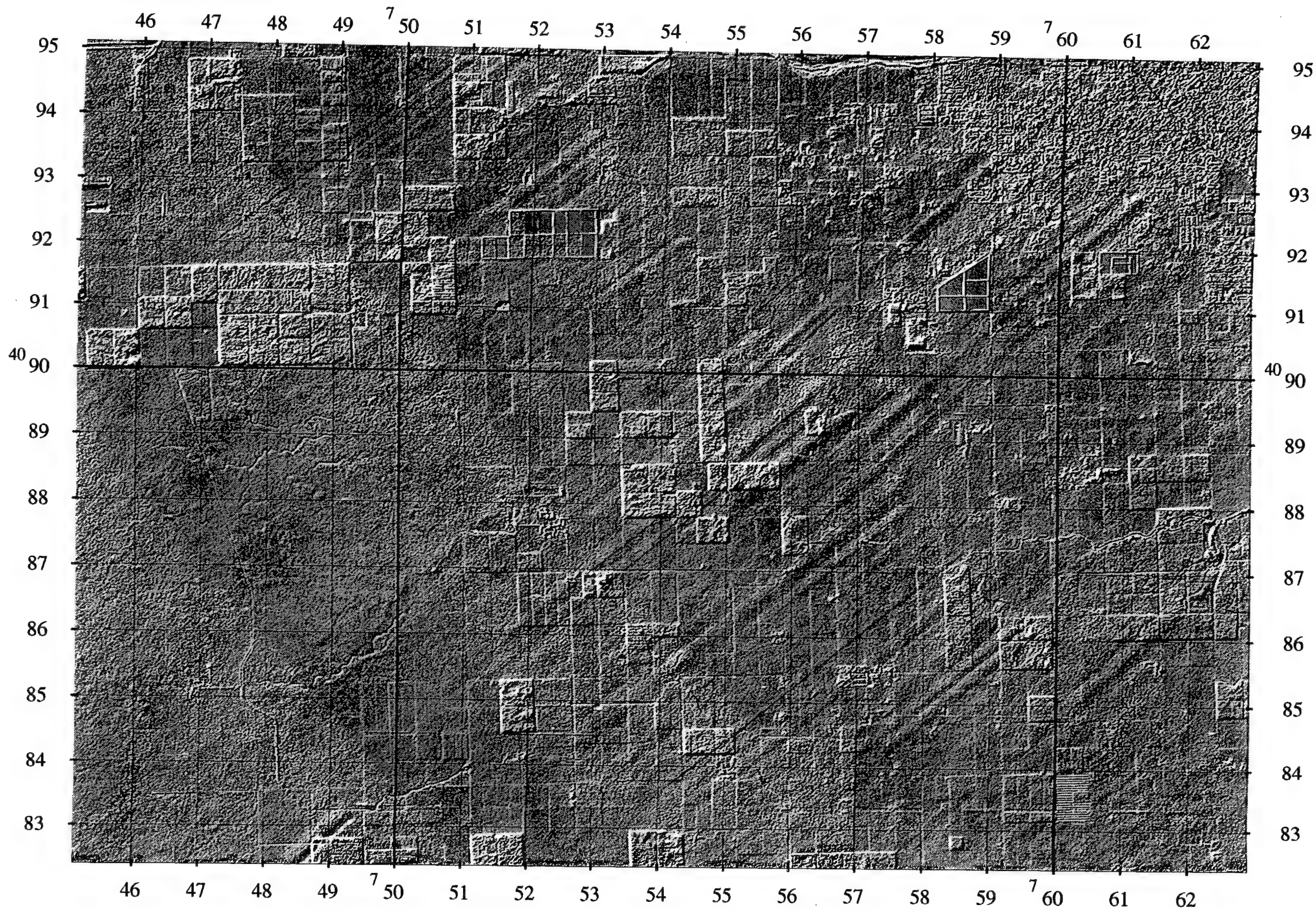

Figure 40. Merging and Motion Artifacts

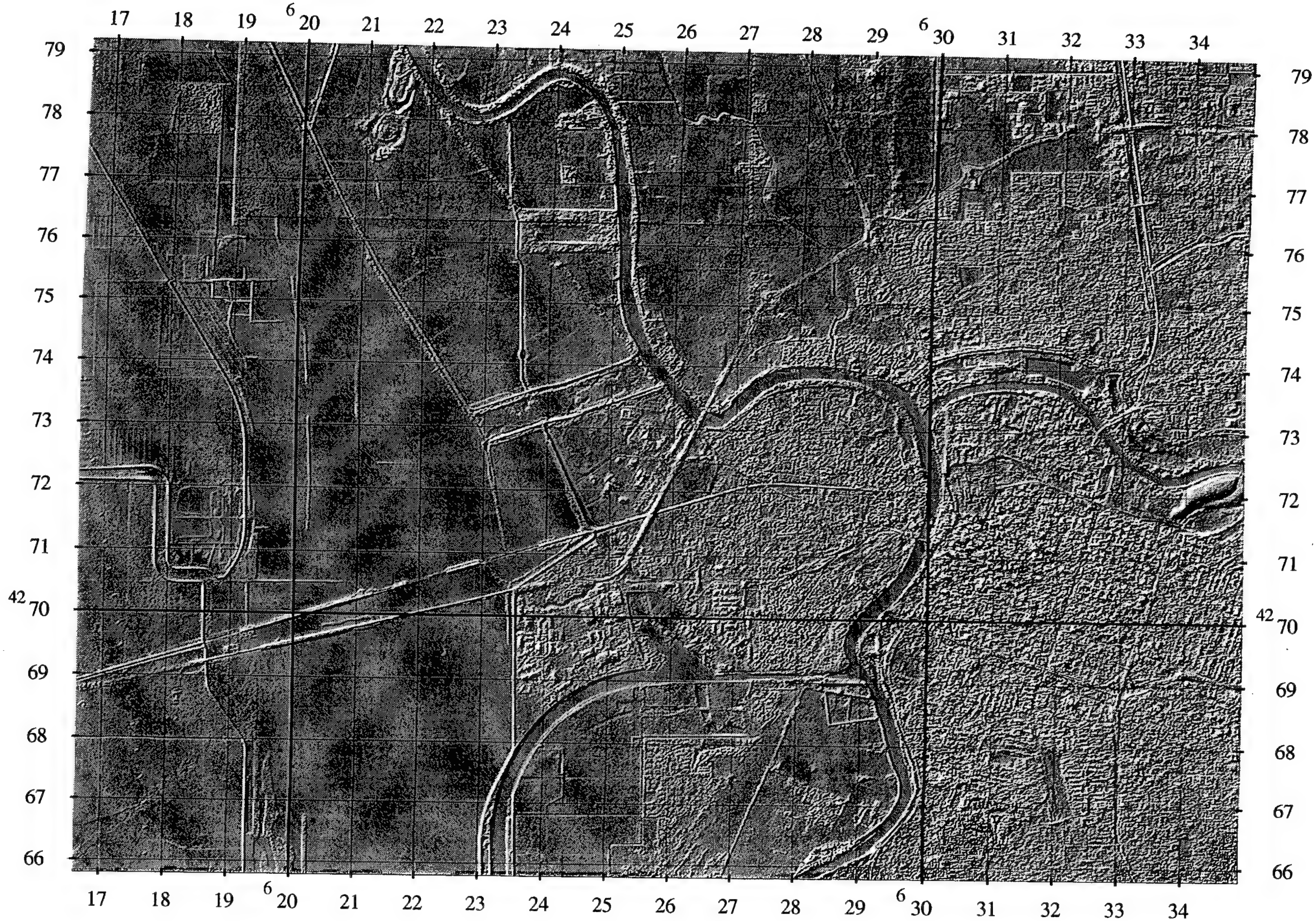

Figure 41. Water Anomalies, corrected, see Figure 8 to Compare

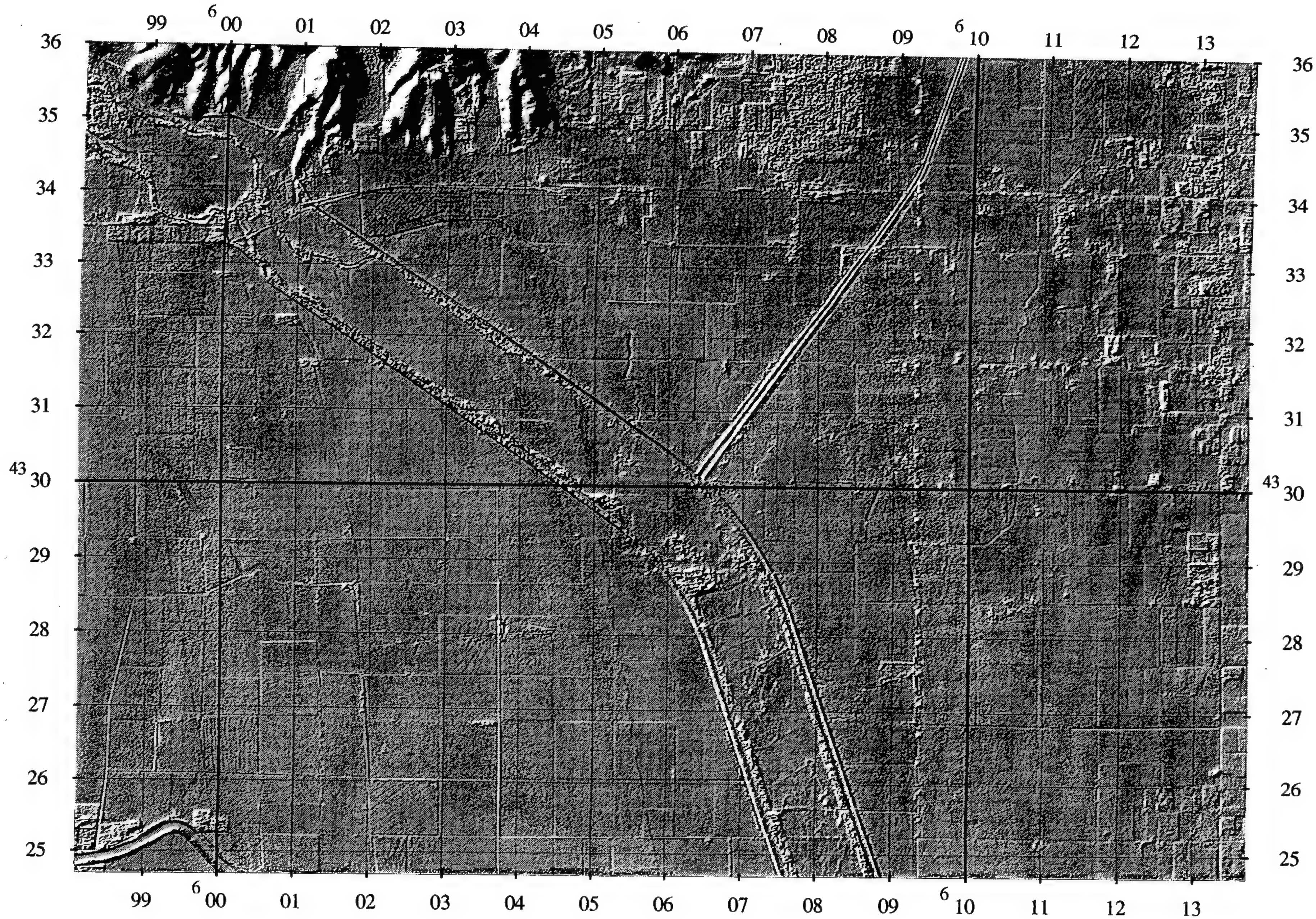

Figure 42. Water Anomalies, corrected, see Figure 9 to Compare

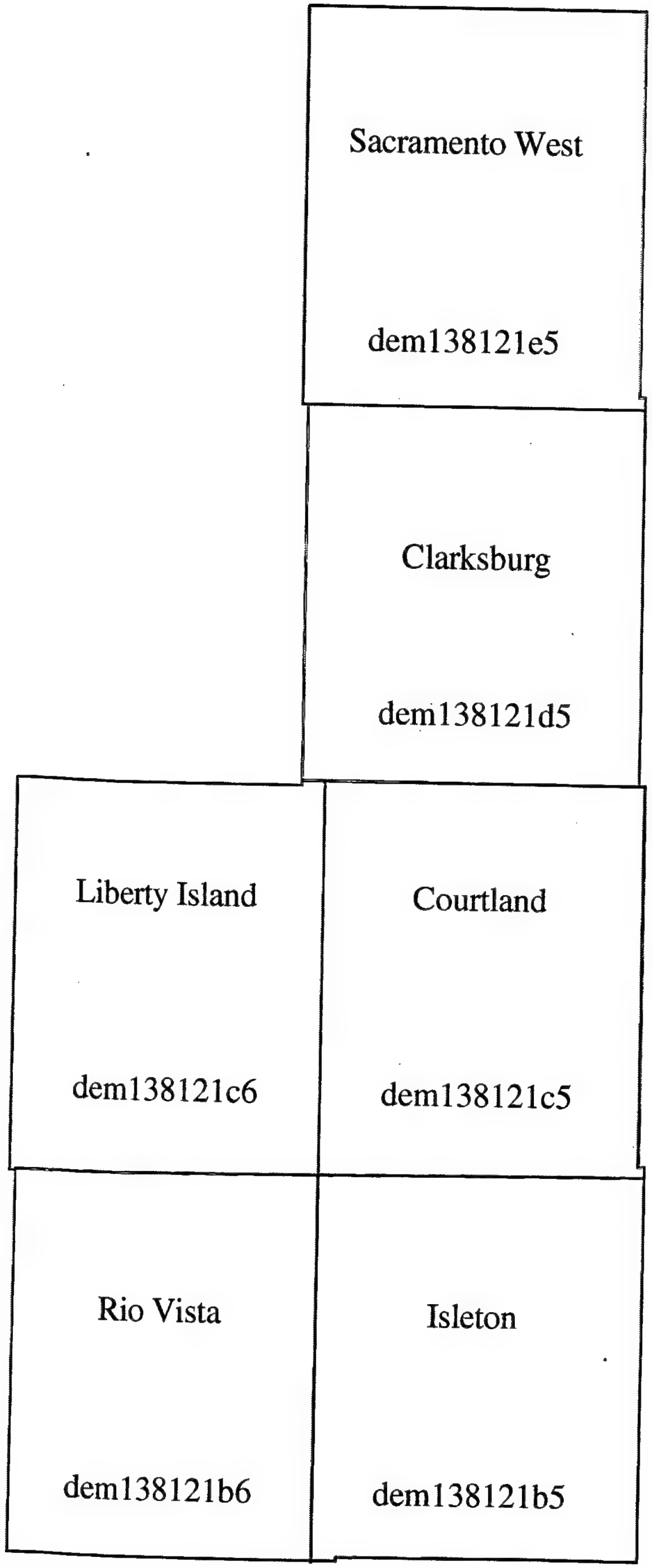

Figure 43. Study Area

In Figure 43, the USGS 7.5 minute quad names are included for reference. Mr. Kehrlein found a 2-m discrepancy between the Intermap DEM and his GPS data. He presented his preliminary findings at the "NASA/FEMA GIS and Applications of Remote Sensing for Disaster Management Conference," 19-21 January 1999 in Washington, D.C. A request was sent to Intermap to obtain the six geoid correction files used to derive the orthometric heights for the final delivery. The geoid correction files are needed to compute the original ellipsoid heights for the vertical height testing.

The first objective was to find out where the 2 m discrepancy was coming from in the Intermap DEM data. The second objective was to find out the relative accuracy of the Intermap DEM data with the current National Geodetic Survey (NGS) High Accuracy Reference Network (HARN) markers. The first test used 27 NGS HARN markers with a 7-km baseline and included NAVD88, GEOID96, and ellipsoid heights. The final vertical accuracy assessment will use approximately 200 HARN markers that fall within the north and south collection areas. The 27 HARN markers used for the first test are shown in Figure 44.

Analysis of the Mean

Mr. Kehrlein supplied a shape file of all the HARN markers for the state of California with the Permanent Identifier (PID) codes, attributes using the NAVD88, GEOID96, and ellipsoid heights in meters. The HARN shape file was imported into Arc/Info as a point coverage. The points falling within the study area were clipped and put into a separate coverage for analysis. Data sheets for the 27 HARN markers were downloaded from the NGS website at *www.ngs.noaa.gov/datasheet.html* using the PIDs to check data consistency. The Intermap ellipsoid height DEM was computed using the formula $h = H + N$ found at the NGS website *www.ngs.noaa.gov/GEOID/geoid.html*. The ellipsoid height, h, is derived by adding the geoid height, N, to the orthometric height, H. The Intermap orthometric, geoid, and ellipsoid heights were extracted using Arc/Info software. An Arc Macro Language (AML) script was written to take elevation values from the three Intermap DEMs. These values were put into an ASCII text file for analysis with X and Y coordinates. The test data in Table 1 are viewable with NGS data marked with the starting prefix NGS and the Intermap data marked with an Int.

The first calculations were made in order to see the differences between the NGS and Intermap values shown in Table 2 using Quattro Pro software. In Figure 45, the NGS and Intermap orthometric heights are compared. The mean value of 2.9021 m is listed in Table 2 under NAVDDIFF. The NGS and Intermap geoid heights are compared in Figure 46 and differ by a mean value of -2.0474 m as shown in Table 2 under GEOIDDIFF. The NGS and Intermap ellipsoidal heights are compared in Figure 47 and differ by a mean value of 0.7752 m as shown in Table 2 under ELLIPDIFF. In Figure 48, all three differences from the NGS and Intermap data sets are displayed. The geoid data GEOIDDIFF in Figure 48 have a striking offset of approximately -2 m. The Intermap geoid data are where the 2 m offset must be originating from and might confirm some of Mr. Kehrlein's initial findings. Further analysis will provide proof of the -2 m offset.

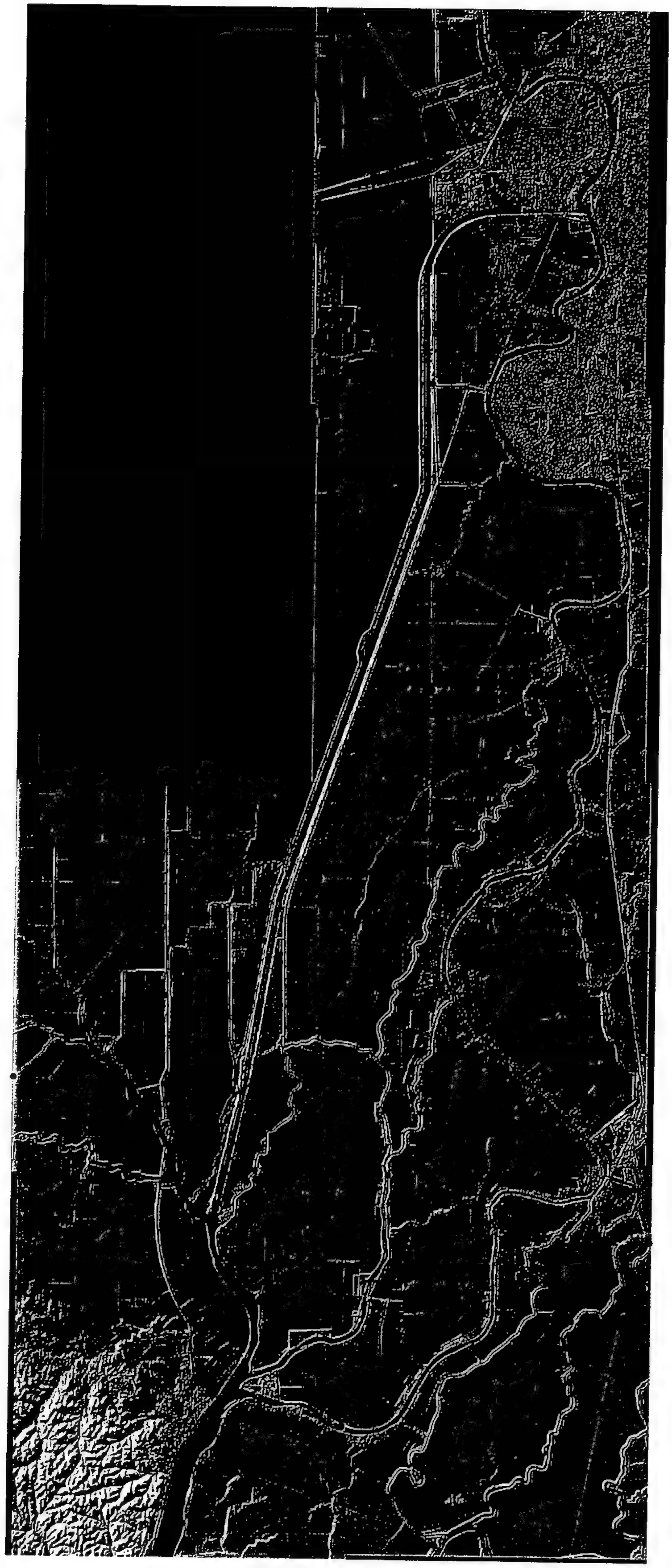

Figure 44. NGS HARN Marker Locations

Table 1. NGS HARN and Intermap Elevations

PID-ID	X-COORD	Y-COORD	NGS-NAVD88	NGS-GEOID96	NGS-ELLIP	INT-ORTHOM	INT-EGM96	INT-ELLIP
AC9226	629333.625	4275042.000	6.1000	-30.69	-24.60	5.0010	-28.71	-23.71
AC9221	625394.500	4274196.000	12.6000	-30.73	-18.10	10.5214	-28.79	-18.27
AC9220	623766.438	4270411.500	8.0100	-30.82	-22.92	5.5379	-28.89	-23.36
JS2248	628020.562	4270201.500	6.4000	-30.79	-24.38	5.0233	-28.82	-23.80
JS4839	630759.375	4262915.500	5.0000	-30.86	-25.88	1.9693	-28.91	-26.94
AC9219	623642.625	4262862.500	9.9100	-30.99	-21.18	4.3491	-29.04	-24.69
JS1556	630477.125	4255755.500	9.1300	-30.98	-21.94	5.7593	-29.05	-23.29
AE9851	623785.438	4251940.500	0.9900	-31.25	-30.36	-0.5717	-29.24	-29.81
AE9855	611668.750	4246328.500	4.7700	-31.73	-27.07	1.6341	-29.55	-27.92
AC9224	611679.938	4246322.500	4.8000	-31.73	-26.98	2.2274	-29.55	-27.33
JS4836	628144.250	4245630.000	8.3000	-31.27	-22.93	6.4758	-29.28	-22.80
AE9850	619788.812	4244943.500	1.2100	-31.56	-30.46	-1.5514	-29.44	-30.99
JS4311	625746.625	4244542.500	8.0600	-31.37	-23.32	5.7013	-29.34	-23.64
JS4310	625737.812	4244523.000	8.4000	-31.37	-23.03	5.8504	-29.34	-23.49
AE9858	614231.250	4240650.500	7.7100	-31.82	-24.22	4.2970	-29.62	-25.32
AE9865	626677.438	4238167.500	8.7600	-31.50	-22.76	5.9430	-29.45	-23.50
AE9859	608710.312	4237630.000	5.4300	-31.96	-26.64	0.1000	-29.77	-29.67
JS4374	617567.688	4234346.000	7.5800	-31.88	-24.41	4.4607	-29.68	-25.22
JS2070	622422.312	4234223.000	6.8700	-31.74	-24.89	2.9323	-29.59	-26.66
JS4837	631954.312	4231916.500	5.7000	-31.47	-25.80	-0.3000	-29.47	-29.77
JS1244	631972.688	4231896.500	6.2700	-31.47	-25.31	2.2852	-29.47	-27.19
AE9867	629161.750	4229006.500	4.1200	-31.64	-27.54	1.2817	-29.57	-28.29
JS2048	612620.000	4228817.500	7.6500	-32.08	-24.52	5.3963	-29.87	-24.47
JS1817	620859.438	4225113.000	8.1200	-31.28	-23.88	5.3334	-29.79	-24.46
JS1926	612496.625	4225071.500	40.7900	-32.13	8.55	38.4099	-29.94	8.47
JS4672	615135.562	4221547.000	5.5000	-32.15	-26.65	1.7203	-29.96	-28.24
JS4846	624314.312	4220831.000	3.7300	-31.96	-28.25	3.7663	-29.81	-26.04
MEAN			7.85	-31.45	-23.68	4.95	-29.41	-24.46
MAX			40.79	-30.69	8.55	38.41	-28.71	8.47
MIN			0.99	-32.15	-30.46	-1.55	-29.96	-30.99
STD			6.91	0.44	6.84	7.06	0.36	7.02

Table 2. Difference Between NGS HARN and Intermap Elevations

PID-ID	Differences NAVDDIFF	GEOIDDIFF	ELLIPDIFF
AC9226	1.0990	-1.9800	-0.8900
AC9221	2.0786	-1.9400	0.1700
AC9220	2.4721	-1.9300	0.4400
JS2248	1.3767	-1.9700	-0.5800
JS4839	3.0307	-1.9500	1.0600
AC9219	5.5609	-1.9500	3.5100
JS1556	3.3707	-1.9300	1.3500
AE9851	1.5617	-2.0100	-0.5500
AE9855	3.1359	-2.1800	0.8500
AC9224	2.5726	-2.1800	0.3500
JS4836	1.8242	-1.9900	-0.1300
AE9850	2.7614	-2.1200	0.5300
JS4311	2.3587	-2.0300	0.3200
JS4310	2.5496	-2.0300	0.4600
AE9858	3.4130	-2.2000	1.1000
AE9865	2.8170	-2.0500	0.7400
AE9859	5.3300	-2.1900	3.0300
JS4374	3.1193	-2.2000	0.8100
JS2070	3.9377	-2.1500	1.7700
JS4837	6.0000	-2.0000	3.9700
JS1244	3.9848	-2.0000	1.8800
AE9867	2.8383	-2.0700	0.7500
JS2048	2.2537	-2.2100	-0.0500
JS1817	2.7866	-1.4900	0.5800
JS1926	2.3801	-2.1900	0.0800
JS4672	3.7797	-2.1900	1.5900
JS4846	-0.0363	-2.1500	-2.2100
Mean	2.9021	-2.0474	0.7752
Max	6.0000	-1.4900	3.9700
Min	-0.0363	-2.2100	-2.2100
STD	1.2978	0.1472	1.2837

t-Test Two Tail	NAVD	GEOID	ELLIP
Paired	0.00	0.00	0.00
Equal Var.	0.14	0.00	0.69

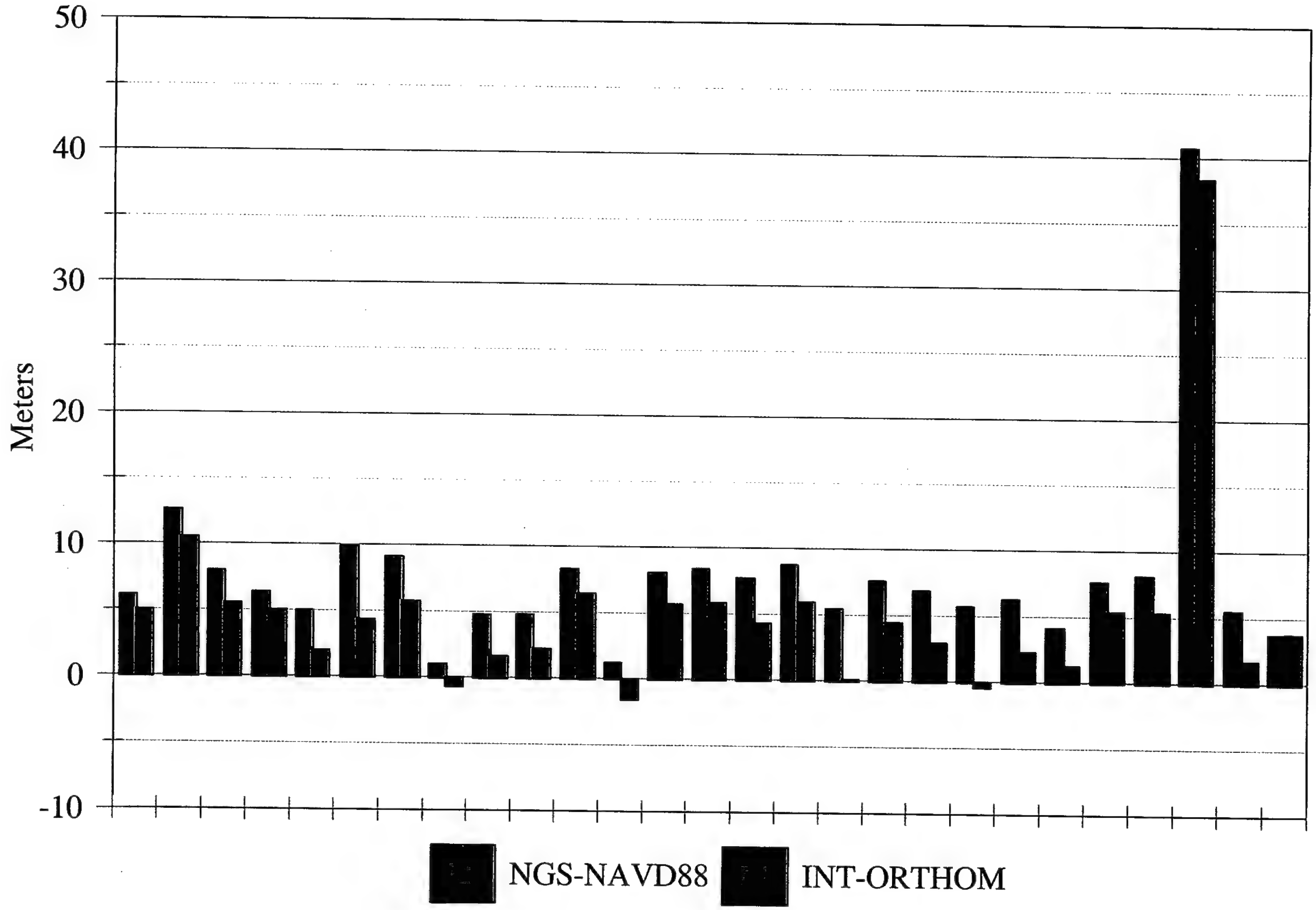

Figure 45. Orthometric Height Difference

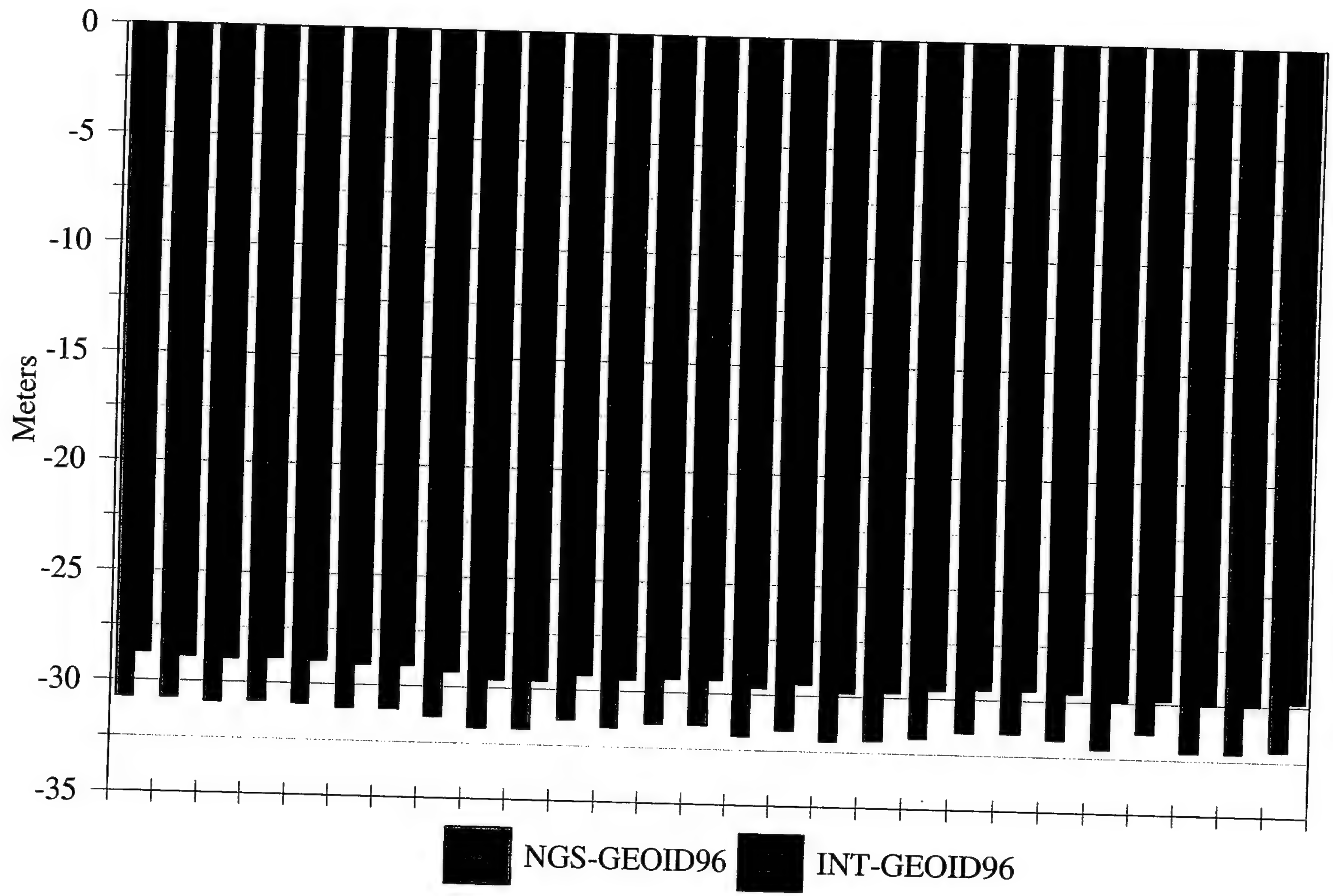

Figure 46. GEOID96 Height Difference

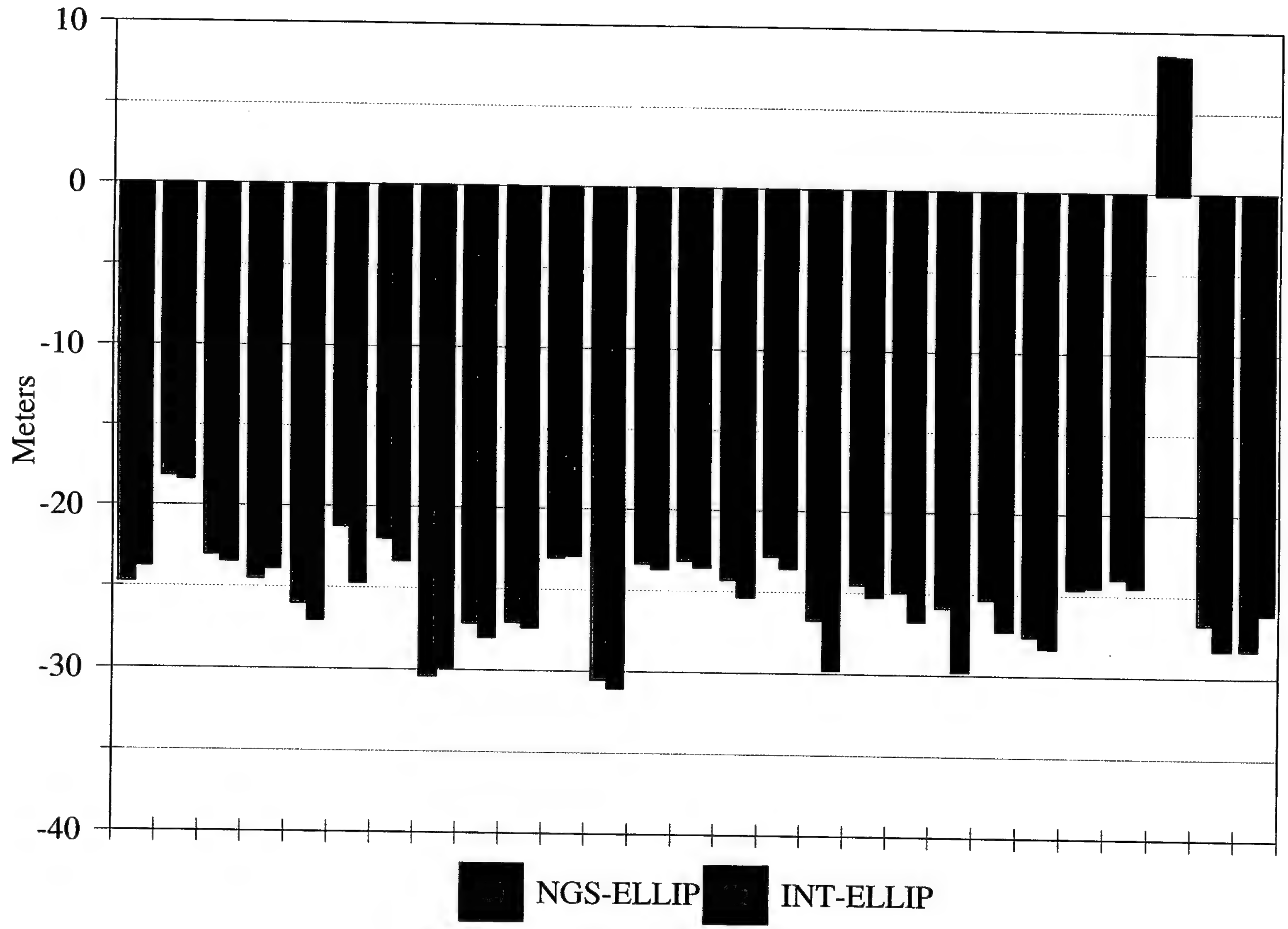

Figure 47. Ellipsoid Height Difference

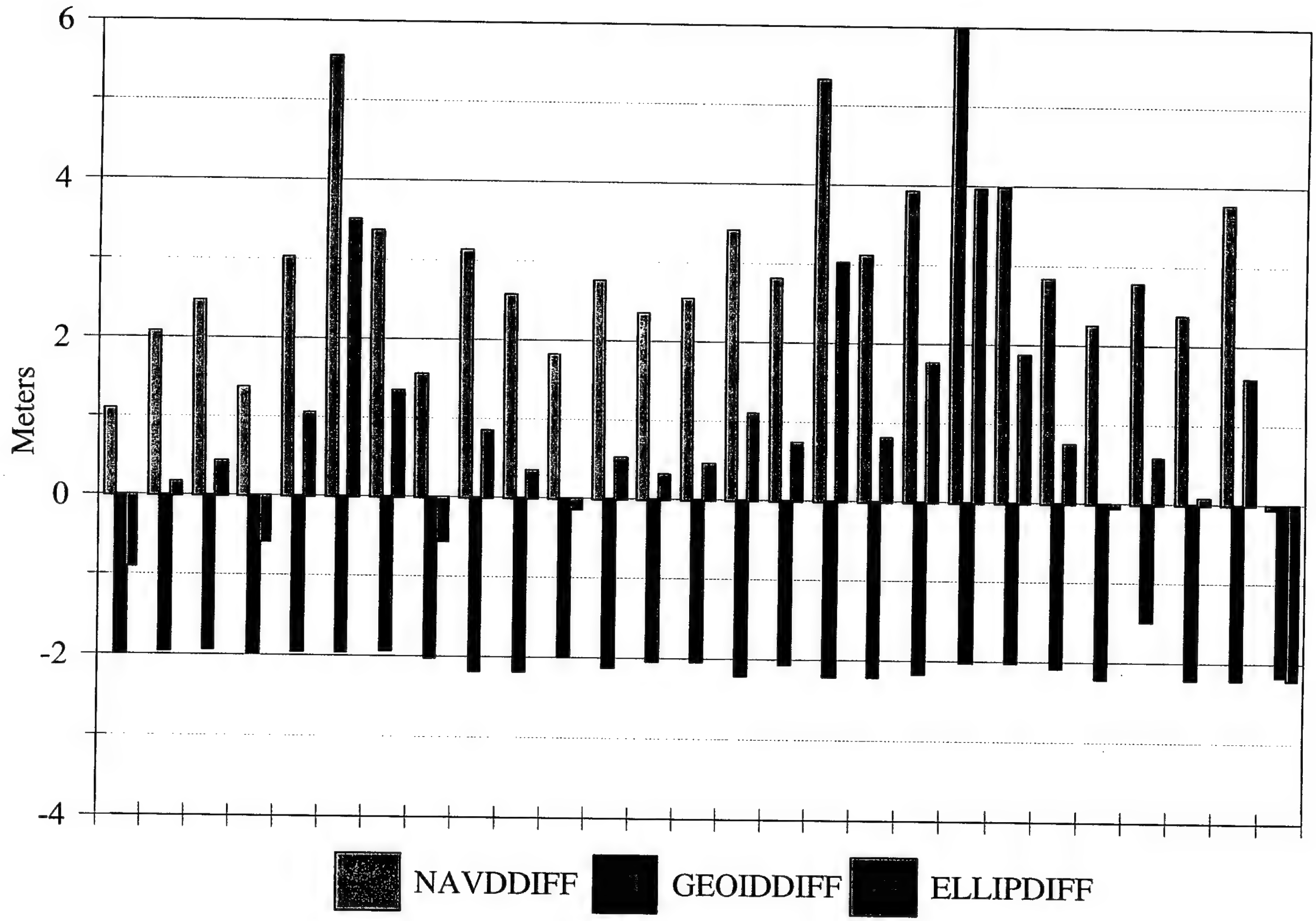

Figure 48. Differences between NGS HARN and Intermap DEM

$$H_0: \mu_1 - \mu_2 = 0$$
$$H_A: \mu_1 - \mu_2 \neq 0$$

Reject H_0 if $t < -t_{\alpha/2}$ or if $t > t_{\alpha/2}$: otherwise, do not reject H_0 .

Test statistic: $t = \dfrac{\bar{d} - \mu_d}{S_d/\sqrt{n}}$ Confidence Interval $\mu_d \pm t_{\alpha/2} \dfrac{S_d}{\sqrt{n}}$

GEOID

t = -18.26 p-value = 0 n = 54 df = 52 $\bar{d} = -2.0474$

95% = [-2.27,-1.82] = 0.45 99% = [-2.35, -1.75] = 0.60

We reject the null hypothesis of no difference and conclude there are significant differences

Figure 49. Paired Two-Tail t - Test

Looking at the basic statistics from Table 2, the NGS and Intermap geoid differences are shown in the GEOIDDIFF column as a mean value of -2.0474, a maximum value of -1.49, a minimum value of -2.21, a standard deviation s = 0.1472 , and number of values n = 27. Two different t-Tests were used to investigate the NGS and Intermap data, but the main focus was on the geoid values. The first test used the paired data sets displayed in Table 1 with p-values calculated using Quattro Pro software. The test of the means used a two-tail paired t-Test with the results shown in Table 2 and Figure 49 using a 95 and 99 percent confidence interval for the geoid values. The paired t-Test results in Table 2 show the p-values = 0 for all three data sets. The conclusion is that the null hypothesis is rejected and the differences are significant.

The second test used a two-tail equal variance t-Test with results shown in Table 2. The equal variance t-Test results are NAVD with a p-value = 0.14, GEOID with a p-value = 0, and ELLIP with a p-value = 0.69. The null hypothesis is rejected for the geoid data, and not rejected for the ELLIP, NAVD data sets. All results were checked using Microsoft Excel and S-PLUS software to confirm the values returned from the two t-Tests. Using the mean value of -2.0474, a final test was run to determine if the mean could be used as a correction value for the geoid data. The mean was added to the Int-Geoid96 column values from Table 1. After applying a mean correction of -2.0474 m to the INT-Geoid96 values, the null hypothesis was not rejected with a p-value = 1.0.

The NGS HARN marker data provided important information about the elevation data on the ground. The vertical accuracy section was supplied to Intermap and made it possible to speed up the search for the cause of the -2 m offset found in the geoid correction file. Intermap agreed the offset occurred in their geoid correction file and agreed to deliver a fourth and final product with the correction for the -2 m offset in late June 1999.

FOURTH AND FINAL DELIVERY

The Intermap fourth and final delivery used the new GEOID96 calculations to eliminate the 2 m offset. The elevation extraction AML was used to extract and dump the data to a file using the NGS HARN coordinates. The new and old Intermap IFSAR values for the orthometric heights can be seen in Table 3 under columns Int-3rd and Int-4th. The new mean for the fourth delivery was reduced from 2.9 m to 0.83 m. The results of the new GEOID96 calculation are shown in Figure 50 with similar elevation values. In Figure 51, the third and fourth delivery differences are shown with the elimination of the 2 m offset.

The least-squares analysis or regression analysis was run on the 27 NGS HARN, and new Intermap IFSAR values are shown in Table 4. The values were calculated in Quattro Pro and checked with the Minitab 12 statistical software package. The calculated r-squared value of 96.6 percent shows a strong relationship between the two data sets shown in Table 4. In Figure 52, a plot of the residuals versus standard normal scores does not show significant deviation from normality. A plot of the residuals versus the fitted values shown in Figure 53 is showing no indication of nonrandomness. Both of these graphs support the assumption of least-squares regression theory, which helps to validate the model. The standardized residuals Z are calculated and shown in Table 4 with outliers located at NGS locations AC9219, AE9859, JS4837, and JS4846 using 1.5 as the cutoff value. The outliers could be due to structures in the path of the collection. Mr. Kehrlein is presently investigating the outliers to determine some of the extreme values noticed in the elevation data. Figure 54 shows the regression plot with a good linear fit. The final RMSE for the study area is 1.35 m using all 27 NGS HARN markers.

CONCLUSION

This contract was successful because of the cooperation between Intermap, TEC, and CalDoC. This cooperation made it possible to develop solutions to quality assurance problems and correct data effectively in order to supply the customer, CalDoC, with the best possible data set for the Sacramento and San Joaquin Valleys. These data will be used by Federal and California state agencies responsible for emergency services, flood plain mapping, power line delineation, and highway development.

Table 3. Old and New Intermap Orthometric Heights

NGS-ID	X-COORD	Y-COORD	NGS-NAVD88	INT-3rd	INT-4th	OLD-DIFF	NEW-DIFF
AC9226	629333.625	4275042.000	6.1000	5.0010	6.9850	1.0990	-0.8850
AC9221	625394.500	4274196.000	12.6000	10.5214	12.4597	2.0786	0.1403
AC9220	623766.438	4270411.500	8.0100	5.5379	7.4695	2.4721	0.5405
JS2248	628020.562	4270201.500	6.4000	5.0233	6.9885	1.3767	-0.5885
JS4839	630759.375	4262915.500	5.0000	1.9693	3.9215	3.0307	1.0785
AC9219	623642.625	4262862.500	9.9100	4.3491	6.3028	5.5609	3.6072
JS1556	630477.125	4255755.500	9.1300	5.7593	7.6914	3.3707	1.4386
AE9851	623785.438	4251940.500	0.9900	-0.5717	1.4437	1.5617	-0.4537
AE9855	611668.750	4246328.500	4.7700	1.6341	3.8097	3.1359	0.9603
AC9224	611679.938	4246322.500	4.8000	2.2274	4.4030	2.5726	0.3970
JS4836	628144.250	4245630.000	8.3000	6.4758	8.4613	1.8242	-0.1613
AE9850	619788.812	4244943.500	1.2100	-1.5514	0.5722	2.7614	0.6378
JS4311	625746.625	4244542.500	8.0600	5.7013	7.7325	2.3587	0.3275
JS4310	625737.812	4244523.000	8.4000	5.8504	7.8819	2.5496	0.5181
AE9858	614231.250	4240650.500	7.7100	4.2970	6.5009	3.4130	1.2091
AE9865	626677.438	4238167.500	8.7600	5.9430	7.9988	2.8170	0.7612
AE9859	608710.312	4237630.000	5.4300	0.1000	2.2966	5.3300	3.1334
JS4374	617567.688	4234346.000	7.5800	4.4607	6.6659	3.1193	0.9141
JS2070	622422.312	4234223.000	6.8700	2.9323	5.0794	3.9377	1.7906
JS4837	631954.312	4231916.500	5.7000	-0.3000	1.7023	6.0000	3.9977
JS1244	631972.688	4231896.500	6.2700	2.2852	4.2873	3.9848	1.9827
AE9867	629161.750	4229006.500	4.1200	1.2817	3.3419	2.8383	0.7781
JS2048	612620.000	4228817.500	7.6500	5.3963	7.6048	2.2537	0.0452
JS1817	620859.438	4225113.000	8.1200	5.3334	7.5201	2.7866	0.5999
JS1926	612496.625	4225071.500	40.7900	38.4099	40.5983	2.3801	0.1917
JS4672	615135.562	4221547.000	5.5000	1.7203	3.9093	3.7797	1.5907
JS4846	624314.312	4220831.000	3.7300	3.7663	5.9170	-0.0363	-2.1870
		Mean	7.8485	4.9464	7.0202	2.9021	0.8283
		Max	40.7900	38.4099	40.5983	6.0000	3.9977
		Min	0.9900	-1.5514	0.5722	-0.0363	-2.1870
		STD	6.9086	7.0587	7.0690	1.2978	1.2965

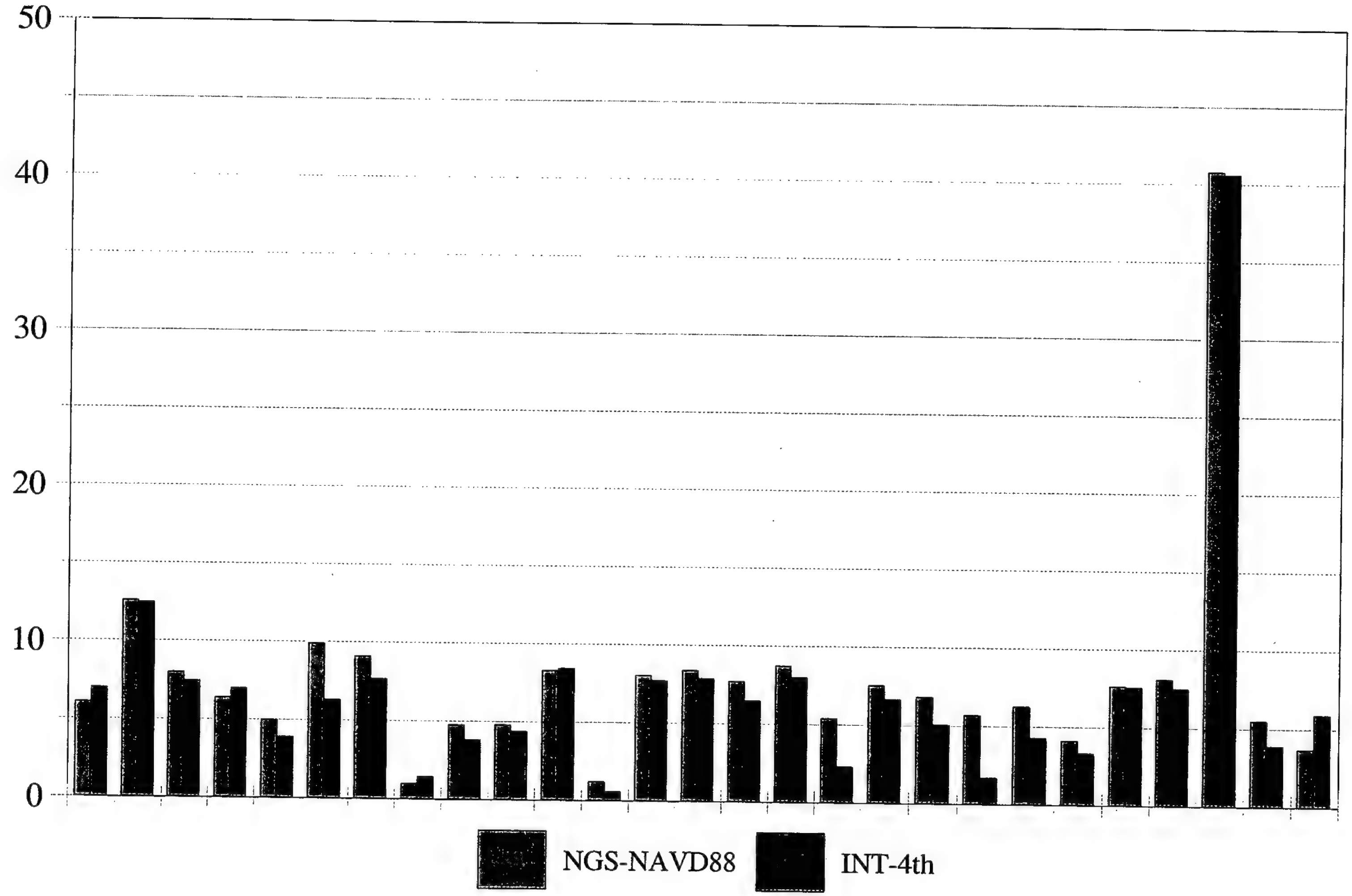

Figure 50. Difference Between NGS HARN and Intermap fourth Delivery Orthometric Heights

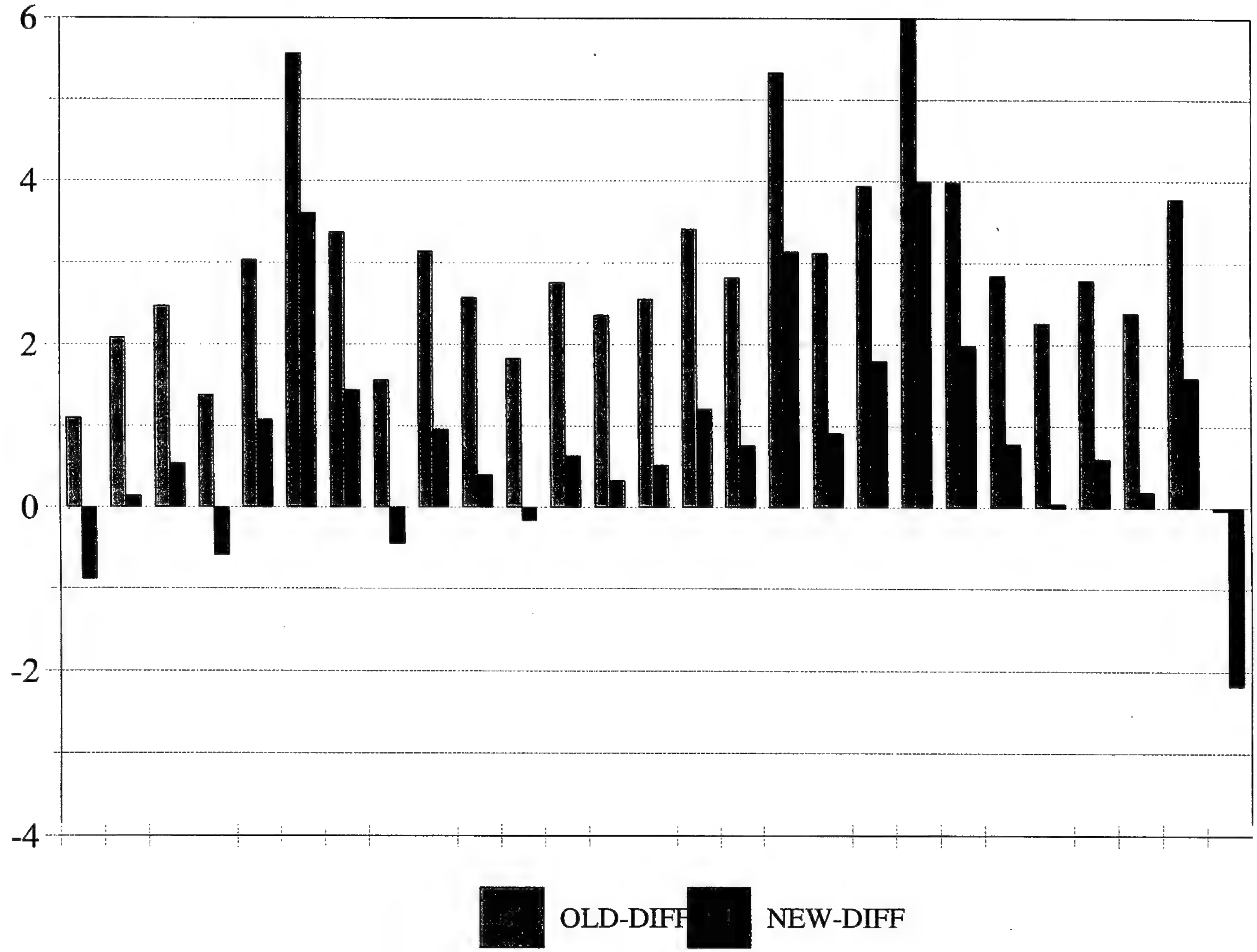

Figure 51. Old and New Intermap Differences

Table 4. Regression Analysis

NGS-ID	$\hat{Y}$	$Y-\hat{Y}$	$(Y-\hat{Y})^2$	$(Y-\overline{Y})^2$	Z
AC9226	5.2614	1.7236	2.9708	0.0012	1.2799
AC9221	11.7996	0.6601	0.4358	29.5886	0.4902
AC9220	7.1826	0.2868	0.0823	0.2018	0.2130
JS2248	5.5632	1.4253	2.0315	0.0010	1.0583
JS4839	4.1549	-0.2334	0.0545	9.6020	-0.1733
AC9219	9.0938	-2.7910	7.7898	0.5147	-2.0724
JS1556	8.3092	-0.6178	0.3817	0.4505	-0.4587
AE9851	0.1214	1.3224	1.7487	31.0969	0.9819
AE9855	3.9236	-0.1139	0.0130	10.3071	-0.0845
AC9224	3.9538	0.4493	0.2018	6.8495	0.3336
JS4836	7.4743	0.9870	0.9742	2.0769	0.7329
AE9850	0.3427	0.2295	0.0527	41.5771	0.1704
JS4311	7.2329	0.4996	0.2496	0.5074	0.3710
JS4310	7.5749	0.3070	0.0942	0.7425	0.2279
AE9858	6.8809	-0.3800	0.1444	0.2697	-0.2822
AE9865	7.9370	0.0618	0.0038	0.9577	0.0459
AE9859	4.5875	-2.2909	5.2481	22.3125	-1.7011
JS4374	6.7501	-0.0842	0.0071	0.1255	-0.0625
JS2070	6.0359	-0.9566	0.9150	3.7668	-0.7103
JS4837	4.8591	-3.1567	9.9649	28.2797	-2.3440
JS1244	5.4324	-1.1451	1.3112	7.4686	-0.8503
AE9867	3.2698	0.0721	0.0052	13.5300	0.0536
JS2048	6.8205	0.7843	0.6152	0.3418	0.5824
JS1817	7.2933	0.2269	0.0515	0.2499	0.1685
JS1926	40.1553	0.4430	0.1962	1127.4889	0.3289
JS4672	4.6579	-0.7486	0.5604	9.6778	-0.5559
JS4846	2.8775	3.0395	9.2384	1.2172	2.2569
	189.5454	0.0000	45.3418	1349.2034	0.0000

Regression Output:

Constant		-0.8745
Std Err of Y Est	RMSE	1.3467
R Squared		0.9664
No. of Observations		27
Degrees of Freedom		25
X Coefficient(s)		1.0059
Std Err of Coef.		0.0375

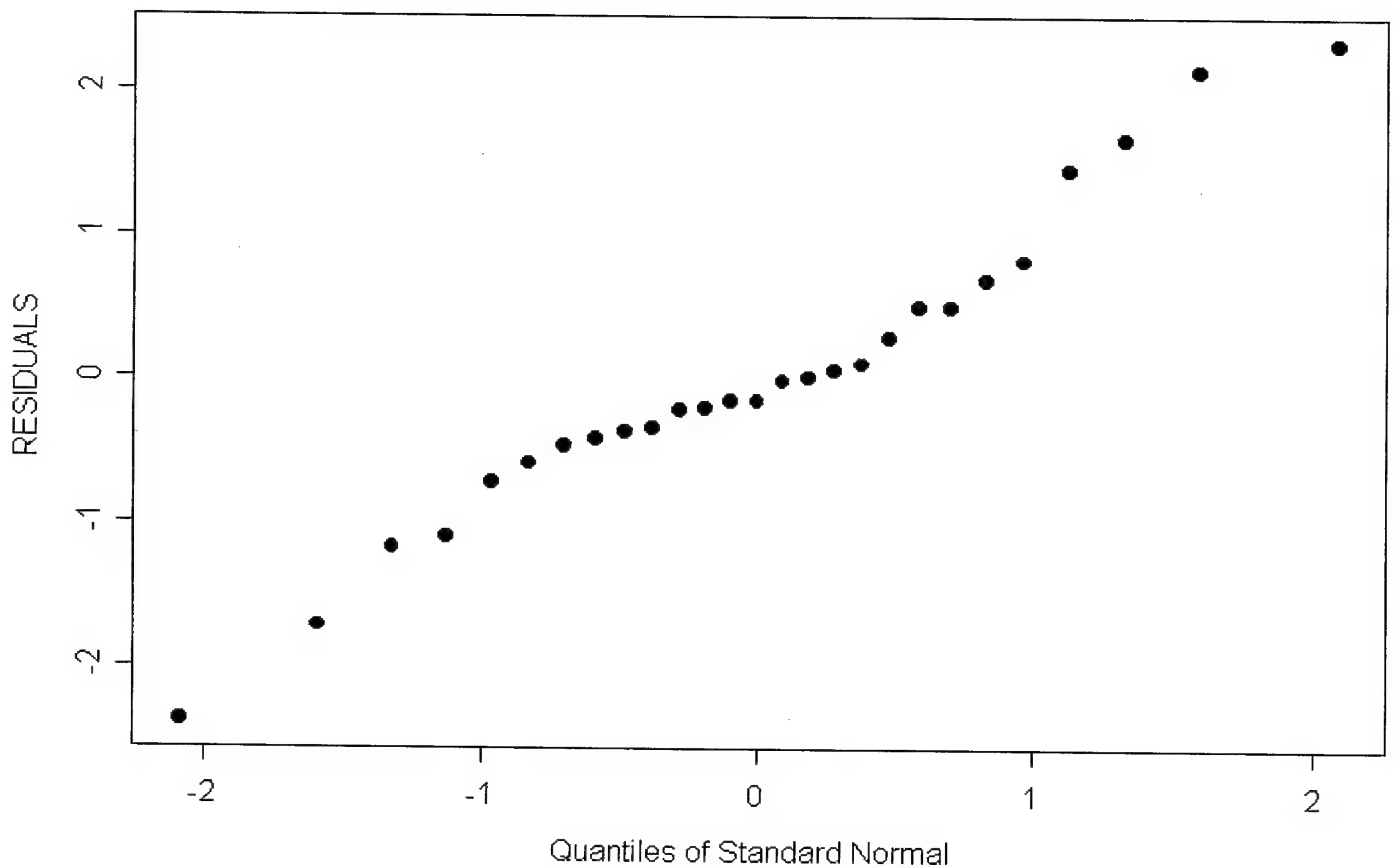

Figure 52. Residuals Versus Normal Scores

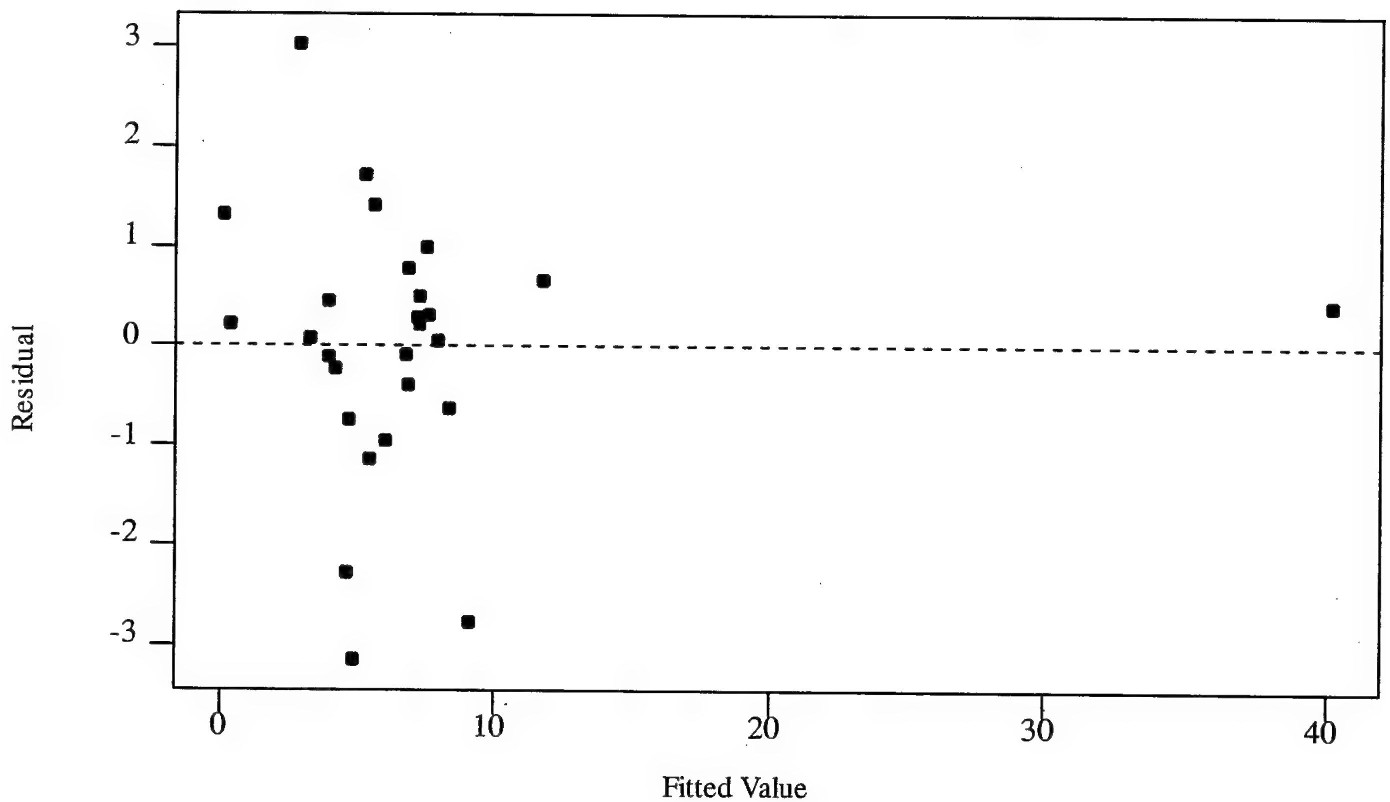

Figure 53. Residuals Versus Fitted Values

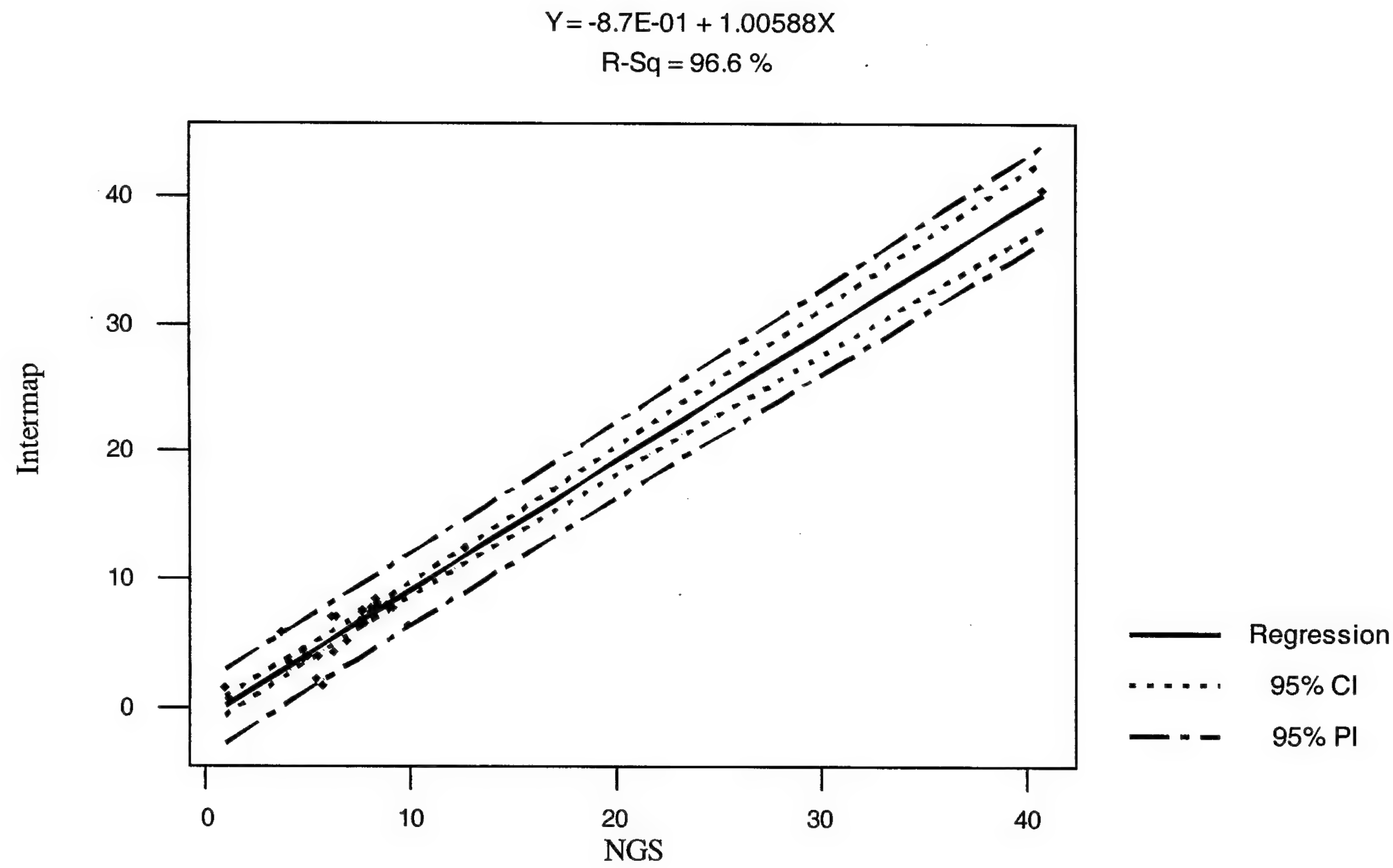

Figure 54. Regression Plot

Appendix 1. Intermap DEM README File 11249801.txt

PROJECT AREA: FEMA California Flood Plain Mapping

PLEASE NOTE: As with most RADAR magnitude data, the low dynamic range in the signal return results in an extremely dark image. This is normal for RADAR magnitude data and can be adjusted using simple image analysis enhancements, such as Linear and Root Stretches. These data are supplied to you in their unenhanced form to allow for a wide range of applications. Enhancements to the imagery are specific from application to application and, as such, performing one enhancement may preclude accurate interpretation of data for other applications. As a consequence of this, Intermap does not enhance the final product thereby allowing the client to define the enhancement best suited to the application and also to facilitate further use of the data for other applications.

File Naming Convention:

Each file has been given a unique 8-digit file name. This file name corresponds to the geographic location of the southeast corner of the map tile. The file name prefix denotes the file type. Each map tile is a 7.5' by 7.5' tile; there are 64 tiles that make up one, 1 deg. by 1 deg. cell.

The file name is read as follows:

First digit: 1-4, the globe has been divided into four quadrants, 1=NW, 2=SW, 3=SE, 4=NE
Second and third digit: Latitude 1 degree intervals, valid range 0-90
Fourth to sixth digit: Longitude 1 degree intervals, valid range 0-180
Seventh digit: Alpha character A-H, row numbers from south to north
Eighth digit: Column number, 1-8, east to west

For example, a map tile covering Stockton, CA would be 137121H2.

Product Description

Processing Level:	GT2
Image Pixels (meters):	2.5
DEM posting (meters):	10
Horizontal Accuracy:	2.5 m (1 sigma)
Vertical Accuracy:	1.5 m (1 sigma)
Data Source:	Synthetic Aperture Radar (SAR)
Sensor:	Airborne Interferometric SAR
Flying Height:	20,000 ft. Above Sea Level
Acquisition Date:	May 1998 (mission 66)
Acquisition Date:	August 1997 (mission 62)
Band:	Xband

Data Parameters and Specifications

Projection:	UTM
Horizontal Datum:	WGS84
Vertical Datum:	Mean Sea Level
Geoid Model:	EGM96 (NIMA96)
Central Scale:	0.9996
UTM Zone:	10 (two tiles will be zone 11)
Central Meridian:	123 deg. west
False Easting (meters):	500,000 m
False Northing (meters):	0 m

DEM File:	136120H1.DEM
Format:	32-bit BIL
UTM Easting (meters):	Min. 755495.0 Max. 767715.0
UTM Northing (meters):	Min. 4084835.0 Max. 4099135.0
Pixels (columns):	1,223
Lines (rows):	1,431
Pixel size (meters):	10.0
Pixel origin:	center of pixel

DEM File:	137121E4.DEM
Format:	32-bit BIL
UTM Easting (meters):	Min. 631885.0 Max. 644105.0
UTM Northing (meters):	Min. 4151215.0 Max. 4165515.0
Pixels (columns):	1,223
Lines (rows):	1,431
Pixel size (meters):	10.0
Pixel origin:	center of pixel

DEM File:	137121G6.DEM
Format:	32-bit BIL
UTM Easting (meters):	Min. 609415.0 Max. 621635.0
UTM Northing (meters):	Min. 4178685.0 Max. 4192985.0
Pixels (columns):	1,223
Lines (rows):	1,431
Pixel size (meters):	10.0
Pixel origin:	center of pixel

DEM File:	137121H7.DEM
Format:	32-bit BIL
UTM Easting (meters):	Min. 598235.0 Max. 610455.0
UTM Northing (meters):	Min. 4192405.0 Max. 4206705.0
Pixels (columns):	1,223
Lines (rows):	1,431
Pixel size (meters):	10
Pixel origin:	center of pixel

DEM File:	138121B4.DEM
Format:	32-bit BIL
UTM Easting (meters):	Min. 630725.0 Max. 642945.0
UTM Northing (meters):	Min. 4220635.0 Max. 4234935.0
Pixels (columns):	1,223
Lines (rows):	1,431
Pixel size (meters):	10
Pixel origin:	center of pixel

DEM File:	138121B5.DEM
Format:	32-bit BIL
UTM Easting (meters):	Min. 619775.0 Max. 631995.0
UTM Northing (meters):	Min. 4220455.0 Max. 4234755.0
Pixels (columns):	1,223
Lines (rows):	1,431
Pixel size (meters):	10
Pixel origin:	center of pixel

DEM File:	138121C7.DEM
Format:	32-bit BIL
UTM Easting (meters):	Min. 597705.0 Max. 609925.0
UTM Northing (meters):	Min. 4234015.0 Max. 4248315.0
Pixels (columns):	1,223
Lines (rows):	1,431
Pixel size (meters):	10
Pixel origin:	center of pixel

DEM File:	138121D7.DEM
Format:	32-bit BIL
UTM Easting (meters):	Min. 597525.0 Max. 609745.0
UTM Northing (meters):	Min. 4247885.0 Max. 4262185.0
Pixels (columns):	1,223
Lines (rows):	1,431
Pixel size (meters):	10
Pixel origin:	center of pixel

DEM File:	138121F8.DEM
Format:	32-bit BIL
UTM Easting (meters):	Min. 586295.0 Max. 598515.0
UTM Northing (meters):	Min. 4275495.0 Max. 4289795.0
Pixels (columns):	1,223
Lines (rows):	1,431
Pixel size (meters):	10
Pixel origin:	center of pixel

DEM File:	138121H7.DEM
Format:	32-bit BIL
UTM Easting (meters):	Min. 596805.0 Max. 609025.0
UTM Northing (meters):	Min. 4303375.0 Max. 4317675.0
Pixels (columns):	1,223
Lines (rows):	1,431
Pixel size (meters):	10
Pixel origin:	center of pixel

DEM File:	139121A5.DEM
Format:	32-bit BIL
UTM Easting (meters):	Min. 618255.0 Max. 630475.0
UTM Northing (meters):	Min. 4317555.0 Max. 4331855.0
Pixels (columns):	1,223
Lines (rows):	1,431
Pixel size (meters):	10
Pixel origin:	center of pixel

DEM File:	139121A6.DEM
Format:	32-bit BIL
UTM Easting (meters):	Min. 607435.0 Max. 619655.0
UTM Northing (meters):	Min. 4317395.0 Max.4331695.0
Pixels (columns):	1,223
Lines (rows):	1,431
Pixel size (meters):	10
Pixel origin:	center of pixel

DEM File:	138121B3.DEM
Format:	32-bit BIL
UTM Easting (meters):	Min. 641665.0 Max. 653885.0
UTM Northing (meters):	Min. 4220825.0 Max. 4235125.0
Pixels (columns):	1,223
Lines (rows):	1,431
Pixel size (meters):	10
Pixel origin:	center of pixel

DEM File:	137120A2.DEM
Format:	32-bit BIL
UTM Easting (meters):	Min. 743955.0 Max. 756175.0
UTM Northing (meters):	Min. 4098365.0 Max. 4112665.0
Pixels (columns):	1,223
Lines (rows):	1,431
Pixel size (meters):	10
Pixel origin:	center of pixel

DEM File:	138121C4.DEM
Format:	32-bit BIL
UTM Easting (meters):	Min. 630485.0 Max. 642705.0
UTM Northing (meters):	Min. 4234505.0 Max.4248805.0
Pixels (columns):	1,223
Lines (rows):	1,431
Pixel size (meters):	10
Pixel origin:	center of pixel

Appendix 2. Intermap Magnitude README File 11209803.txt

PROJECT AREA: FEMA California Flood Plain Mapping

PLEASE NOTE: As with most RADAR magnitude data, the low dynamic range in the signal return results in an extremely dark image. This is normal for RADAR magnitude data and can be adjusted using simple image analysis enhancements, such as linear and root stretches. These data are supplied in their unenhanced form to allow for a wide range of applications. Enhancements to the imagery are specific from application to application and, as such, performing one enhancement may preclude accurate interpretation of data for other applications. As a consequence of this, Intermap does not enhance the final product thereby allowing the client to define the enhancement best suited to the application and also to facilitate further use of the data for other applications.

File Naming Convention:

Each file has been given a unique 8-digit file name. This file name corresponds to the geographic location of the southeast corner of the map tile. The file name prefix denotes the file type. Each map tile is a 7.5' by 7.5' tile; there are 64 tiles that make up one, 1deg. by 1 deg. cell.

The file name is read as follows:

First digit: 1-4, the globe has been divided into four quadrants, 1=NW, 2=SW, 3=SE, 4=NE
Second and third digit: Latitude 1 degree intervals, valid range 0-90
Fourth to sixth digit: Longitude 1 degree intervals, valid range 0-180
Seventh digit: Alpha character A-H, row numbers from south to north
Eighth digit: Column number, 1-8, east to west

For example, a map tile covering Stockton, CA would be 137121H2.

Product Description

Processing Level:	GT2
Image Pixels (meters):	2.5
DEM posting (meters):	10
Horizontal Accuracy:	2.5 m (1 sigma)
Vertical Accuracy:	1.5 m (1 sigma)
Data Source:	Synthetic Aperture Radar (SAR)
Sensor:	Airborne Interferometric SAR
Flying Height:	20,000 ft. Above Sea Level
Primary Look:	East (mission 62)
Acquisition Date:	August 1997
Band:	Xband

Data Parameters and Specifications

Projection:	UTM
Horizontal Datum:	WGS84
Vertical Datum:	Mean Sea Level
Geoid Model:	EGM96(NIMA96)
Central Scale:	0.9996
UTM Zone:	10
Central Meridian:	123 deg. west
False Easting (meters):	500,000.0 m
False Northing (meters):	0 m

ORI File:	139121A4.MAG
Format:	8-bit BIL
UTM Easting (meters):	Min. 629071.0 Max. 641288.5
UTM Northing (meters):	Min. 4317731.5 Max. 4332029.0
Pixels (columns):	4,888
Lines (rows):	5,720
Pixel size (meters):	2.5
Pixel origin:	upper left

ORI File:	139121A5.MAG
Format:	8-bit BIL
UTM Easting (meters):	Min. 618261.0 Max. 630478.5
UTM Northing (meters):	Min. 4317551.5 Max. 4331849.0
Pixels (columns):	4,888
Lines (rows):	5,720
Pixel size (meters):	2.5
Pixel origin:	upper left

ORI File:	139121A6.MAG
Format:	8-bit BIL
UTM Easting (meters):	Min. 607441.0 Max. 619658.5
UTM Northing (meters):	Min. 4317391.5 Max. 4331689.0
Pixels (columns):	4,888
Lines (rows):	5,720
Pixel size (meters):	2.5
Pixel origin:	upper left

ORI File:	139121A7.MAG
Format:	8 bit BIL
UTM Easting (meters):	Min. 596631.0 Max. 608848.5
UTM Northing (meters):	Min. 4317241.5 Max. 4331539.0
Pixels (columns):	4,888
Lines (rows):	5,720
Pixel size (meters):	2.5
Pixel origin:	upper left

ORI File:	139121A8.MAG
Format:	8-bit BIL
UTM Easting (meters):	Min. 585811.0 Max. 598028.5
UTM Northing (meters):	Min. 4317111.5 Max. 4331409.0
Pixels (columns):	4,888
Lines (rows):	5,720
Pixel size (meters):	2.5
Pixel origin:	upper left

ORI File:	139121B4.MAG
Format:	8-bit BIL
UTM Easting (meters):	Min. 628831.0 Max. 641048.5
UTM Northing (meters):	Min. 4331601.5 Max. 4345899.0
Pixels (columns):	4,888
Lines (rows):	5,720
Pixel size (meters):	2.5
Pixel origin:	upper left

ORI File:	139121B5.MAG
Format:	8-bit BIL
UTM Easting (meters):	Min. 618041.0 Max. 630258.5
UTM Northing (meters):	Min. 4331431.5 Max. 4345729.0
Pixels (columns):	4,888
Lines (rows):	5,720
Pixel size (meters):	2.5
Pixel origin:	upper left

ORI File:	139121B6.MAG
Format:	8-bit BIL
UTM Easting (meters):	Min. 607241.0 Max. 619458.5
UTM Northing (meters):	Min. 4331261.5 Max. 4345559.0
Pixels (columns):	4,888
Lines (rows):	5,720
Pixel size (meters):	2.5
Pixel origin:	upper left

ORI File:	139121B7.MAG
Format:	8-bit BIL
UTM Easting (meters):	Min. 596451.0 Max. 608668.5
UTM Northing (meters):	Min. 4331111.5 Max. 4345409.0
Pixels (columns):	4,888
Lines (rows):	5,720
Pixel size (meters):	2.5
Pixel origin:	upper left

ORI File:	139121B8.MAG
Format:	8-bit BIL
UTM Easting (meters):	Min. 585651.0 Max. 597868.5
UTM Northing (meters):	Min. 4330981.5 Max. 4345279.0
Pixels (columns):	4,888
Lines (rows):	5,720
Pixel size (meters):	2.5
Pixel origin:	upper left

ORI File:	139121C4.MAG
Format:	8-bit BIL
UTM Easting (meters):	Min. 628591.0 Max. 640808.5
UTM Northing (meters):	Min. 4345481.5 Max. 4359779.0
Pixels (columns):	4,888
Lines (rows):	5,720
Pixel size (meters):	2.5
Pixel origin:	upper left

ORI File:	139121C5.MAG
Format:	8-bit BIL
UTM Easting (meters):	Min. 617821.0 Max. 630038.5
UTM Northing (meters):	Min. 4345301.5 Max. 4359599.0
Pixels (columns):	4,888
Lines (rows):	5,720
Pixel size (meters):	2.5
Pixel origin:	upper left

ORI File:	139121C6.MAG
Format:	8-bit BIL
UTM Easting (meters):	Min. 607041.0 Max. 619258.5
UTM Northing (meters):	Min. 4345131.5 Max. 4359429.0
Pixels (columns):	4,888
Lines (rows):	5,720
Pixel size (meters):	2.5
Pixel origin:	upper left

ORI File:	139121C7.MAG
Format:	8-bit BIL
UTM Easting (meters):	Min. 596261.0 Max. 608478.5
UTM Northing (meters):	Min. 4344991.5 Max. 4359289.0
Pixels (columns):	4,888
Lines (rows):	5,720
Pixel size (meters):	2.5
Pixel origin:	upper left

ORI File:	139121C8.MAG
Format:	8-bit BIL
UTM Easting (meters):	Min. 585491.0 Max. 597708.5
UTM Northing (meters):	Min. 4344851.5 Max. 4359149.0
Pixels (columns):	4,888
Lines (rows):	5,720
Pixel size (meters):	2.5
Pixel origin:	upper left

ORI File:	139121D8.MAG
Format:	8-bit BIL
UTM Easting (meters):	Min. 585321.0 Max. 597538.5
UTM Northing (meters):	Min. 4358721.5 Max. 4373019.0
Pixels (columns):	4,888
Lines (rows):	5,720
Pixel size (meters):	2.5
Pixel origin:	upper left

ORI File:	139122A1.MAG
Format:	8-bit BIL
UTM Easting (meters):	Min. 575001.0 Max. 587218.5
UTM Northing (meters):	Min. 4316991.5 Max. 4331289.0
Pixels (columns):	4,888
Lines (rows):	5,720
Pixel size (meters):	2.5
Pixel origin:	upper left

ORI File:	139122B1.MAG
Format:	8-bit BIL
UTM Easting (meters):	Min. 574851.0 Max. 587068.5
UTM Northing (meters):	Min. 4330861.5 Max. 4345159.0
Pixels (columns):	4,888
Lines (rows):	5,720
Pixel size (meters):	2.5
Pixel origin:	upper left

ORI File:	139122C1.MAG
Format:	8-bit BIL
UTM Easting (meters):	Min. 574711.0 Max. 586928.5
UTM Northing (meters):	Min. 4344731.5 Max. 4359029.0
Pixels (columns):	4,888
Lines (rows):	5,720
Pixel size (meters):	2.5
Pixel origin:	upper left

ORI File:	139122D1.MAG
Format:	8-bit BIL
UTM Easting (meters):	Min. 574571.0 Max. 586788.5
UTM Northing (meters):	Min. 4358601.5 Max. 4372899.0
Pixels (columns):	4,888
Lines (rows):	5,720
Pixel size (meters):	2.5
Pixel origin:	upper left

ORI File:	139122D2.MAG
Format:	8-bit BIL
UTM Easting (meters):	Min. 563811.0 Max. 576028.5
UTM Northing (meters):	Min. 4358501.5 Max. 4372799.0
Pixels (columns):	4,888
Lines (rows):	5,720
Pixel size (meters):	2.5
Pixel origin:	upper left